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THE EFFECTS OF TEMPERATURE, ILLUMINATION AND PRESSURE ON THE VERTICAL DISTRIBUTION OF ZOOPLANKTON[1, 2]

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ABSTRACT

Thirteen 24-hour plankton stations were worked in the Florida Current and counts made for four species of siphonophores. Depth, temperature and illumination data accompanied all net hauls. An equation is developed relating the depth of each species at any given time to external conditions of temperature, illumination and pressure. This involves null value of each at which there is no stimulus to vertical movement, and factors giving relative response to each of the three environmental influences. The nulls are not solved here; the factors show a diurnal rhythm and also a progressive change from predominance of light control in the upper part of the population to predominance of temperature control in the lower part.

INTRODUCTION

In earlier studies (Moore, 1953, 1955; Moore, et al, 1953) it was shown that changes in the temperature and illumination are reflected in corresponding changes in the noon vertical distribution of various kinds of oceanic zooplankton. A balance appears to be attained, such that the stimulus to move upwards into warmer water just counteracts the stimulus to move downwards to a lower level of illumination. Furthermore, the deeper-living individuals in a population are more influenced by a given temperature change than the shallower ones while the latter are more influenced by a given change of illumination. That there is such a gradation of reaction through a population is to be expected since all individuals are not concentrated at a single depth but rather are spread over a wide range of external conditions.

In an attempt to relate, mathematically, the depth occupied and the external conditions, the general conditions of temperature and

[1]Contribution No. 161 from The Marine Laboratory, University of Miami.
[2]Contribution No. 864 from the Woods Hole Oceanographic Institution.

illumination were expressed as the depths of a selected isotherm and isolume, and all data were translated into deviations from annual mean values of these depths at noon. Similarly the depth of the organism in question at noon was expressed as deviation from its annual mean noon depth. This had the advantage of allowing results for a number of different species to be grouped together and thus increasing the significance of results based on somewhat inadequate data. When the depths, temperatures and illuminations had been converted to deviations, partial regressions were calculated, and it was in this form that the plankton behavior was expressed. The population was separately analyzed at nine levels from 10% to 90%, the percentage representing the proportion of the population above that level. For each such level we solved the equation

$$d = T \text{ fac. } t + I \text{ fac. } i \qquad (1)$$

where the factors are obtained as partial regressions and t, i, and d are the deviations from the mean of isotherm, isolume and plankton depth respectively.

This equation, in effect, related vertical movement of the animals to vertical movements of a given temperature and illumination level, and as such gave a close prediction of where the plankton would be found under widely varying conditions. At a test of its applicability, the equation predicted that the plankton at a station 40 miles east of Miami should be at least twice as deep as at a ten mile station. Roane (1954) verified this for the siphonophores, the mean day level, averaged for eight species, being 79 meters at the 10 mile station and 253 meters at the 40 mile station.

The type of equation given above yielded good values for the depth of the organism in terms of the displacement of isolines but proved useless in trying to relate depths with actual temperatures and illuminations *in situ*. Furthermore, some of the partial regressions obtained were greater than 1.0, suggesting an over-compensation by the animals. The present paper presents a modified equation which allows the actual values to be used rather than the deviations and appears to come closer to representing the actual mechanism involved.

Since we commence with counts of organisms in net hauls whose sampling variation is unknown, it seems valueless to attempt to determine the significance of the final figures arrived at. It must therefore be strongly emphasized that these figures should be considered as establishing certain general trends but not as being accurate

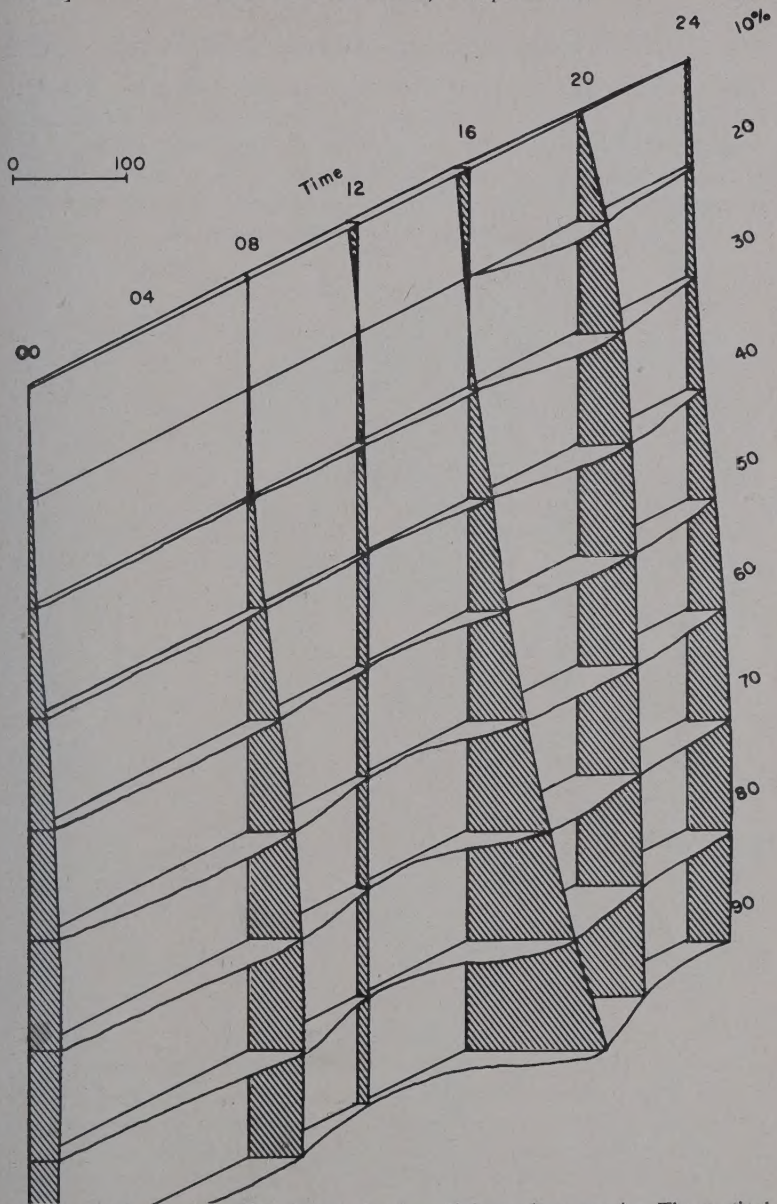

FIGURE 1. Mean values of T. factors for four Siphonophore species. The vertical coordinates represent percentage levels in the population. The horizontal coordinates are time and strength of factor. A vertical section (hatched) shows, for a given time, the variation in factor strength through the population. A horizontal section shows the diurnal change in the factor at a given percentage level.

in detail. It should be stated that the data used have served mainly for the development of methods. The diurnal rhythms found were considered questionable until more material had been collected and analyzed. Analysis of copepod behavior, based on a new and larger series of hauls, has confirmed the general pattern of these rhythms and has justified the presentation of the present series.

Material and Methods

Net hauls were available from thirteen stations at different locations in the Florida Current off Miami. At each, from six to nine hauls were made at different depths, and this series was repeated through a 24 hour period. However, weather and other conditions sometimes curtailed operation so that the number of stations usable varies with time of day. The collecting methods were those previously described. All counts were reduced to the equivalent of a one-mile tow and are accompanied by depth, temperature and illumination data. The full series of nets could not be towed simultaneously, so values have been interpolated at standard times at four hour intervals through the 24 hours.

The present treatment does not apply to conditions of complete darkness. We have therefore omitted those night hours when there was no moonlight. Unfortunately, these were mostly at 0400 hours so that the remaining data for this hour is insufficient for analysis.

The material was drawn from samples, collected for other purposes, in part under a joint program of the Marine Laboratory of the University of Miami and the National Geographic Society, in part under the contract number NObsr-57146 for the Office of Naval Research and in part under a grant from the Rockefeller Foundation. The analyses were carried out under contracts listed above and also under a National Science Foundation grant and under contract number NObsr-43270 at Woods Hole Oceanographic Institution.

Equilibrium Equation

The only formulation which would account for the observed facts required the inclusion of a third factor which was correlated linearly with depth. This is assumed to be pressure, and there is some evidence that pressure may control vertical movement of plankton (Hardy and Bainbridge, 1951; Knight-Jones and Quasim, 1955). Since our assumed pressure factor is derived from depths, the unit used is meters

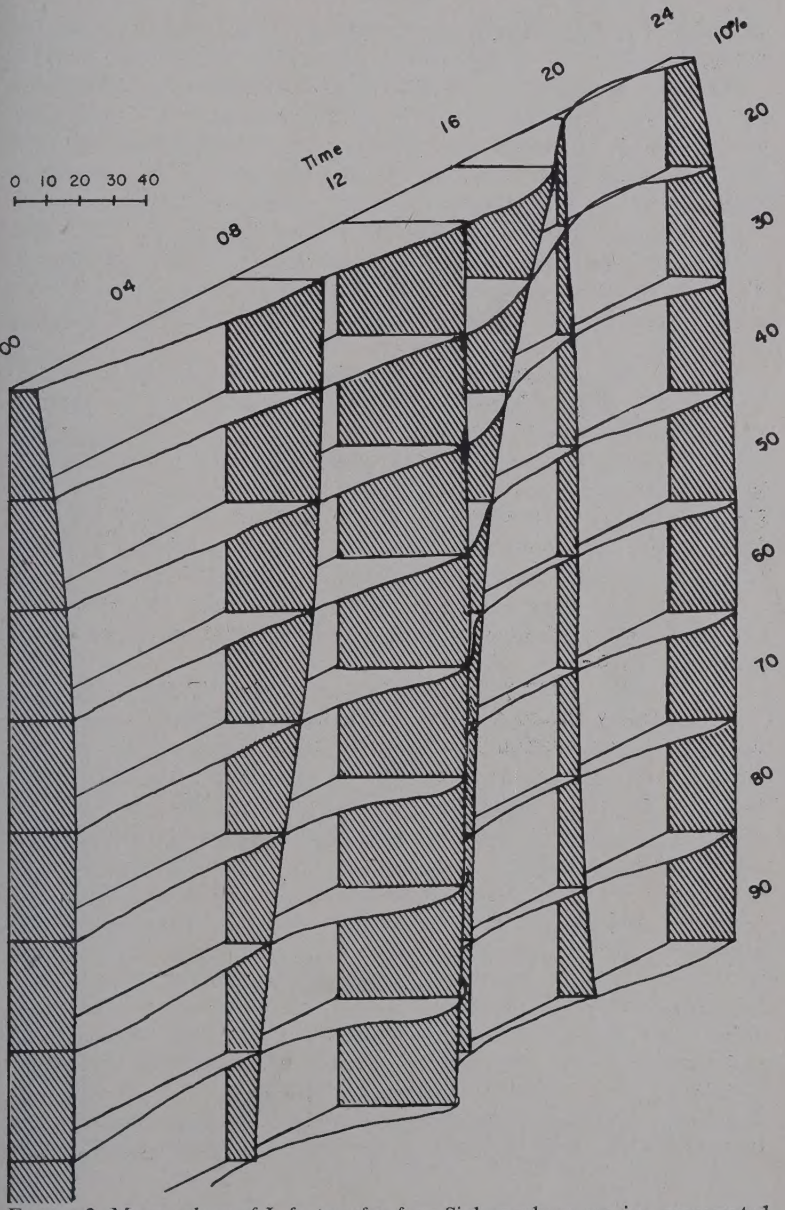

FIGURE 2. Mean values of I. factors for four Siphonophore species, represented as in Fig. 1.

of water. The light unit is the exponent to the base ten with full sunlight rated at 10^2. Temperatures are in degrees centigrade.

It is assumed that there are null values of temperature, illumination and pressure (T_n, I_n and P_n) at which an animal has no tendency to move upwards or downwards. This does not exclude the possibility of their oscillating between two limiting values since the null would represent the mean of these. It is further assumed that the strength of the animal's response is linearly proportional to the difference between the null values and the *in situ* values of the condition to which the animal is exposed. While this is improbable, it is necessary as an approximation if the solution is not to become impossibly complex at the present stage.

We may therefore represent the strengths of the stimuli to vertical movement as $T\text{-}T_n$, $I\text{-}I_n$ and $P\text{-}P_n$ where T, I, and P are the temperature, illumination and pressure *in situ*, and T_n, I_n and P_n, the null values of each. To equate relative responses to the three stimuli, it is necessary to designate three factors, T. fac., I. fac., and P. fac. Since these are determined relatively and not absolutely, one of them, P. fac., is assumed to be always equal to one. If it varies, certain changes are implied, which will be discussed later.

If the animals of a given part of the population, and at a given time, have achieved an equilibrium between their responses to the three stimuli, then

$$\text{T fac. } (T\text{-}T_n) + \text{I fac. } (I\text{-}I_n) + \text{P fac. } (P\text{-}P_n) = 0 \quad (2)$$

It is initially assumed that the organisms at different percentage levels of the population may differ in their responses and in their nulls. There may also be differences in diurnal rhythm. There may be some delay in response to changing conditions but both net hauls and scattering layer records have frequently demonstrated the ability of plankton to keep pace in its vertical movements with the rapidly changing illumination at sunrise and sunset. Thus, for each time and percentage level we have an array of occasions with different, known values of T, I and P. With these it is possible to obtain a solution to part of the equation, namely the three factors. Equation 2 may be rewritten:

$$\text{T fac. } T + \text{I fac. } I + \text{P fac. } P = \text{T fac. } T_n + \text{I fac. } I_n + \text{P fac. } P_n \quad (3)$$

and the sum of the right hand part may be temporarily designated Tot. fac.

Solution by partial regressions gives us the best fitting values of T fac., I fac. and Tot. fac.; P fac. is assumed to equal one. The

values for T and I factors are given in Tables 5-8, while Figures 1 and 2 are smoothed curves drawn from the mean value for the four. The 0400 hour series, as stated above, is missing, and the 2000 hour means are based on two species only. The other two being inadequately represented.

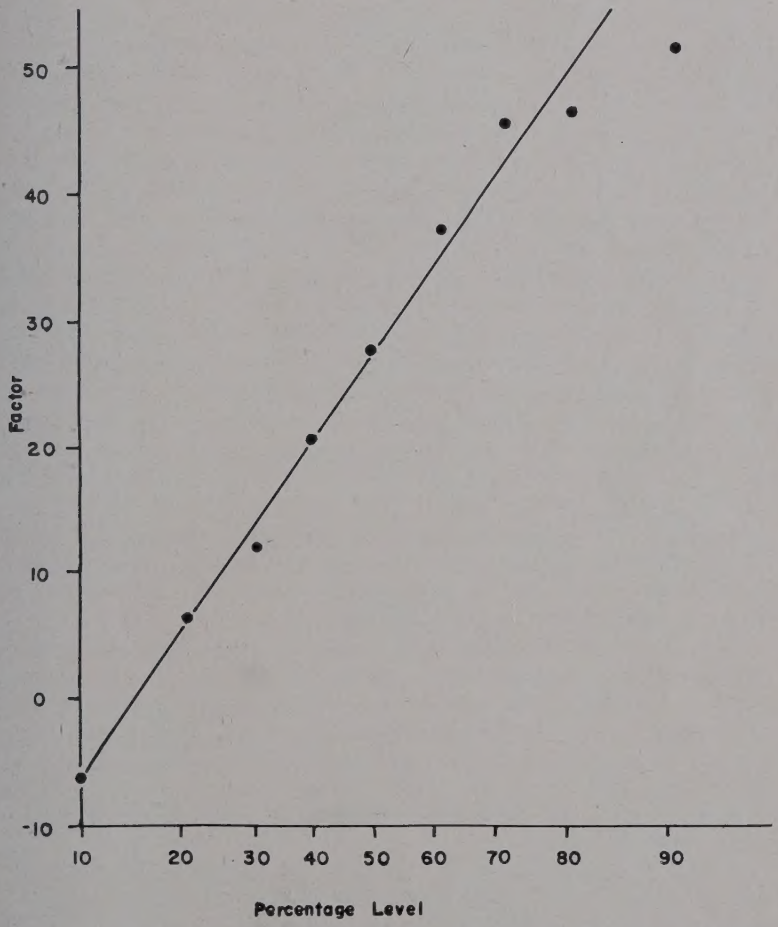

FIGURE 3. Mean of T. factors for four Siphonophore species, taking all times, in relation to percentage level. These are plotted on linear probability paper.

Bearing in mind that only generalizations, and not details, should be taken from these results, one or two particular aspects may be considered. In the first place, earlier work indicated a change from dominant illumination sensitivity in the upper part of the population to dominant temperature sensitivity in the lower part. If we take the means for all hours for the present data we find this to be true here also. In the earlier work it was stated that the partial regressions, which were not strictly equivalent to the present ones, seemed to vary linearly with percentage level. The present values approach a straight line on linear probability paper (Figs. 3, 4) which suggest that they represent a more or less normal distribution of the two factors through the population. Again we must not draw too detailed inferences from the data. The misfit of the 90% values, particularly for the I factor, may well be due to the inadequacy of the original sampling since this is the sparsest part of the population.

We originally assumed that the pressure factor was constant with a value of one. In view of the variation in the other two factors it seems probable that the pressure factor also varies. Since they are measured in units relative to the pressure factor at any given time and percentage level, the values shown in Figures 1 and 2 would have to be correspondingly modified. This might result in a change in the gradient of a factor through the population or in its diurnal rhythm in itself or one of the other two factors. Changes in the pressure factor could, however, in no way modify the diurnal and percentage level changes in the relative strengths of the temperature and illumination factors. In other words the change from shallow illumination sensitivity to deep temperature sensitivity is real, as is the diurnal change in their relations.

The second generalization which may be made from the data is that there is a marked diurnal rhythm in the factors. In general there is a marked noon drop in the temperature factor with a corresponding increase in the illumination factor. The 1600 hours series appears to indicate an over-compensation following the noon condition. The 2000 hours and 0800 hours conditions are so similar that it seems unlikely that the missing 0400 hours series would be much different.

It can be shown that, even if the pressure factor varies, there will still be a diurnal rhythm in the relative strengths of the temperature and illumination factors. The ratio $\frac{\text{T fac}}{\text{I fac}}$ can be calculated, and

expressed as the mean for all percentage levels. To eliminate the effects of the few negative values for the factors, a constant can be added throughout which makes all values positive. This does not affect the general trend of the means. Table 1 shows the mean values of $\frac{\text{T fac.} + 14}{\text{I fac.} + 3}$

TABLE 1

Time	00	04	08	12	16	20
Ratio	17.73	—	3.06	0.45	4.66	10.22

Discussion

At an earlier stage in these studies it was shown that there was a very similar pattern of response to temperature and illumination in widely different groups of plankton animals (Moore, et al, 1953). An average siphonophore (mean of 8 species) was very similar to an average chaetognath (9 species), pteropod (6 species) or copepod (18 species). The depth at which they were found most closely reflected isolume movements in the upper part of the population and isotherm movement in the lower part. This was later confirmed in more detail for siphonophores and chaetognaths (Moore 1955). Coming to individual species, the pattern is the same, although here we are relating depth to actual temperature and illumination, and not to movements of isotherms and isolumes. If we take, for each species, the mean value of temperature and illumination factor for all percentage levels, and exclude 2000 hours, for which only two of the species were analyzed, we obtained the following values:

TABLE 2
Mean Values of Factors

	T fac.	I fac.
Abylopsis eschscholtzii	20.7	21.1
A. tetragona	17.3	19.9
Eudoxoides mitra	23.6	20.0
Chelophyes appendiculata	24.9	20.1

The differences are very small and perhaps not even significant. Yet these species characteristically live at very different levels. The following mean day levels are given by Roane (loc. cit.). In the Florida Current the cold water comes closer to the surface at the 10 mile than at the 40 mile station. Depths at the 40 mile station are the means of Roane's values for the two generations.

TABLE 3
MEAN DAY LEVELS. DEPTHS IN METERS

	Bermuda	Florida Current 10 Mile	Florida Current 40 Mile
Abylopsis eschscholtzii	40	58	171
A. tetragona	55	104	188
Eudoxoides mitra	125	134	270
Chelophyes appendiculata	75	74	221

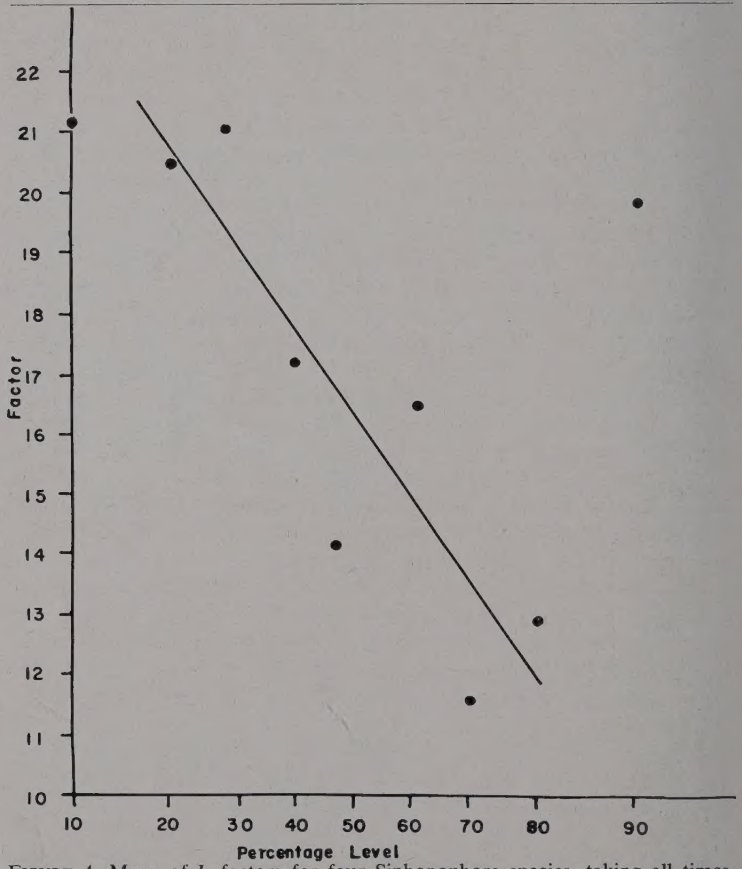

FIGURE 4. Mean of I. factors for four Siphonophore species, taking all times, in relation to percentage level. These are plotted on linear probability paper.

The present paper does not present the analysis of the second part of the equation, which yields the null values of temperature, etc., at which the animals are not stimulated to vertical movement. The similarity of their responses to unit change of temperature, etc., suggests that the difference in the levels characteristically occupied is more likely to reflect specific differences in their null values.

It is not surprising that there should be a regular change through the population in the relative strength of temperature and illumination response. It is true that random movement about an optimal depth would result in vertical spread but it is hard to believe that animals with identical behavior characteristics would tolerate the wide range of external conditions which they would encounter. Roane (loc. cit.) gives the following vertical spreads between the 25% and 75% levels. For the entire population, 0% - 100%, these would be still greater.

TABLE 4

VERTICAL SPREAD IN METERS

	Bermuda	Florida Current	
		10 Mile	40 Mile
Abylopsis eschscholtzii	80	51	219
A. tetragona	25	63	234
Fudoxoides mitra	105	65	209
Chelophyes appendiculata	130	81	134

If such spreads are not due to random movement they must represent a sorting of the population resulting from individually different behavior characteristics.

The existence of a diurnal rhythm in degree of response to the same stimulus is also in accord with the numerous examples of rhythms known in other animals. While some of these are timed by varying external conditions, many others are known to be timed by an internal "clock." It has been suggested that the observed rhythm reflects a conditioning to the much more intense light in the middle of the day or is even an effect of the response scale not being linearly related to the illumination scale. This at first sounds reasonable, since the light changes many million-fold diurnally, whereas the temperatures and pressures encountered have a far smaller range. However, the animals to a great extent regulate their level so as to follow a constant illumination and the actual light

changes they encounter during their diurnal movement are of comparable magnitude with the temperature and pressure changes.

It is interesting to make a tentative comparison of the relative effects of the three environmental conditions considered. A change of one light unit represents a ten-fold change in light. Temperature is in degrees centigrade and one pressure unit is equivalent to one meter of water or about a tenth of an atmosphere. Both temperature and illumination factors have mean values of about twenty, so a ten-fold light change, or a 1°C temperature change is equivalent to about two atmosphere. Dr. P. F. Scholander suggested that it would be more logical to consider volume changes rather than pressure changes and that the reciprocal of the pressure might yield better correlation than the pressure istelf. This was tested, but found not to be true.

We wish to express our indebtedness to many people for assistance. The Captain, crew and various scientists on board made possible the extensive collecting at sea. This work was done from The Marine Laboratory R/V PHYSALIA. Illumination and temperature data were worked up by various members of the Laboratory staff. The counting was done partly by the senior author and partly by D. C. Roane (1954). Thanks are due to various members of Woods Hole Oceanographic Institution for helpful criticism and suggestions. Finally invaluable assistance in statistics was received from Dr. F. Smith of the University of Michigan, Dr. C. C. Taylor of the U. S. Fish and Wildlife Service in Woods Hole, Mrs. Helen Roberts of Woods Hole Oceanographic Institution, and Miss A. Feinstein, of The Marine Laboratory, University of Miami.

TABLE 5

Abylopsis eschscholtzii

	Temperature Factors			
%	00.00	08.00	12.00	16.00
10	+3.8	—5.1	—3.3	—17.0
20	+8.0	—11.9	—15.1	—18.7
30	+9.4	—11.8	—1.2	+0.6
40	+13.6	+1.9	+16.3	+20.5
50	+12.1	+6.7	+37.7	+38.2
60	+47.8	+36.0	—4.6	+57.4
70	+178.4	+25.6	—3.3	+52.5
80	+12.3	+42.4	+22.5	+63.6
90	+15.3	+41.8	+3.3	+69.8

TABLE 5 (Cont.)

ILLUMINATION FACTORS

%	00.00	08.00	12.00	16.00
10	+2.0	+21.0	+38.2	+37.9
20	+6.7	+37.9	+47.3	+23.9
30	+21.3	+43.5	+40.8	+12.8
40	+16.0	+33.7	+26.6	+5.4
50	—0.6	+33.6	+3.4	+13.9
60	+2.2	+36.2	+65.3	+11.2
70	—58.1	+15.1	+53.6	+20.7
80	+32.2	+4.8	+11.9	+12.7
90	+30.7	+7.9	+44.6	+4.6

TABLE 6

Abylopsis tetragona

TEMPERATURE FACTORS

%	00.00	08.00	12.00	16.00
10	—5.3	+11.7	+8.8	—9.8
20	—1.4	+16.2	—0.9	+0.9
30	+6.9	+2.8	—0.5	+4.6
40	+26.9	+15.3	+5.8	+11.4
50	+12.4	+30.3	—3.8	+31.0
60	+24.6	+46.1	—4.1	+37.3
70	+22.7	+46.2	—2.6	+43.8
80	+25.1	+52.0	—1.7	+40.7
90	+33.1	+33.9	—2.8	+62.7

ILLUMINATION FACTORS

%	00.00	08.00	12.00	16.00
10	+7.2	+16.6	+25.5	+36.4
20	+20.6	+21.4	+38.7	+26.1
30	+21.5	+28.3	+38.1	+22.8
40	+12.9	+16.9	+21.3	+18.1
50	+21.3	+10.1	+38.9	+10.4
60	+16.0	+4.0	+40.0	+7.5
70	+15.2	+5.4	+37.6	+4.7
80	+16.2	+1.1	+37.0	+11.9
90	+15.3	+13.7	+37.5	+2.1

TABLE 7

Eudoxoides mitra

	Temperature Factors				
%	00.00	08.00	12.00	16.00	20.00
10	+4.8	—13.3	—2.8	—7.0	—0.1
20	+5.0	—6.7	—3.4	—6.0	+36.2
30	+6.8	+15.8	—9.7	+9.9	+39.7
40	+21.5	+29.6	—3.4	+19.5	+56.5
50	+31.3	+45.5	—4.2	+34.2	+55.1
60	+36.6	+58.6	—2.7	+56.7	+72.0
70	+42.7	+65.6	—7.2	+99.8	+73.2
80	+63.2	+71.6	—5.5	+105.2	+79.2
90	+34.7	+46.1	—2.0	+4.6	+67.7

	Illumination Factors				
%	00.00	08.00	12.00	16.00	20.00
10	+25.5	+25.5	+37.9	+30.8	+1.6
20	+24.4	+26.0	+38.6	+29.1	+3.8
30	+24.6	+17.1	+45.4	+19.5	—3.3
40	+21.0	+11.6	+37.1	+15.5	+7.1
50	+19.5	+5.5	+38.0	+10.7	+7.8
60	+18.5	+0.8	+37.0	+4.7	+9.4
70	+16.7	+0.0	+37.0	—8.1	—2.7
80	+5.6	—1.5	+36.4	—17.4	+6.1
90	+15.3	+13.3	+38.5	+21.0	+7.3

TABLE 8

Chelophyes appendiculata

	Temperature Factors				
%	00.00	08.00	12.00	16.00	20.00
10	+5.3	——	——	——	——
20	+8.3	+6.9	+31.2	+17.4	+12.5
30	+10.5	+3.8	+17.3	+25.6	+38.2
40	+18.7	+0.6	+13.4	+27.6	+30.0
50	+26.2	+34.1	+26.9	+40.1	+26.4
60	+36.5	+24.9	+9.7	+58.9	+42.0
70	+33.8	+33.0	+8.2	+68.9	+31.6
80	+30.9	+37.7	+19.2	+72.5	+64.7
90	+54.2	+35.3	+5.6	——	+34.9

TABLE 8 (Cont.)

ILLUMINATION FACTORS

%	00.00	08.00	12.00	16.00	20.00
10	—7.4	——	——	——	——
20	—6.7	+24.1	+22.8	+20.3	—1.8
30	+15.4	+25.9	+32.2	+14.4	—0.1
40	+14.5	+26.3	+33.1	+12.0	+4.7
50	+12.6	+9.5	+25.6	+6.4	+4.8
60	+11.6	+13.2	+35.4	+1.4	+3.3
70	+15.6	+10.2	+36.9	+6.3	+8.7
80	+21.2	+8.6	+31.1	+11.2	+11.6
90	+13.8	+12.8	+35.8	——	+17.6

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THE OCCURRENCE OF THE MACRURAN *GNATHOPHYLLOIDES MINERII* SCHMITT ON THE SPINES OF THE EDIBLE SEA-URCHIN *TRIPNEUSTES ESCULENTUS* LESKE IN BARBADOS

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ABSTRACT

The macruran shrimp *Gnathophylloides minerii* Schmitt is recorded from Barbados living on the test and along the spines of the edible sea-urchin *Tripneustes esculentus* Leske. Time of spawning, appearance of the larvae and differences in coloration of the sexes are discussed, and both adults and larvae are figured.

During the course of studies of the edible sea-urchin *Tripneustes esculentus* Leske in Barbados, numerous specimens of the small Macruran *Gnathophylloides minerii* Schmitt were found on the test and spines of the urchin. *Gnathophylloides* has previously been recorded from coral reefs at Porto Rico (Schmitt, 1933, 1935) and Dr. Fenner Chace, Jr. of the United States National Museum has kindly informed me that it has also been taken at Montego Bay, Jamaica, on the spines of *"Toxopneustes" variegatus;* from Palm Beach, Florida, on the spines of *Tripneustes* and from Gran Roque, Venezuela. This is the first record of the occurrence of the species in Barbados.

Gnathophylloides is exceedingly abundant in Barbados and as many as a dozen individuals, both male and female, have been taken from a single urchin. They move about over the test of the urchin, clinging to the spines with their ambulatory limbs. Their food is apparently chiefly planktonic, consisting of tiny particles wafted into the mouth or entrapped among the hairs of the appendages. They were also observed feeding on bits of debris on the spines of the urchin and they presumably find food amongst the bits of weed with which the urchin is usually covered.

Schmitt's description (1933) of the species is based upon a male type specimen. The sexes are of about equal size but there are sexual differences in pigmentation and in the form of the large chelae. In both males and females the dorsal surface of the thorax and abdomen, reaching halfway down the sides, is porcellanous white in life. In

females the remainder of the thorax and abdomen is covered with fine darkly pigmented spots. In males the pigmented area is a strip running from the base of the eye to the base of the telson (see Fig. 1a, b). The white dorsal surface of the thorax and abdomen makes the animal almost invisible among the white spines of the urchin. The

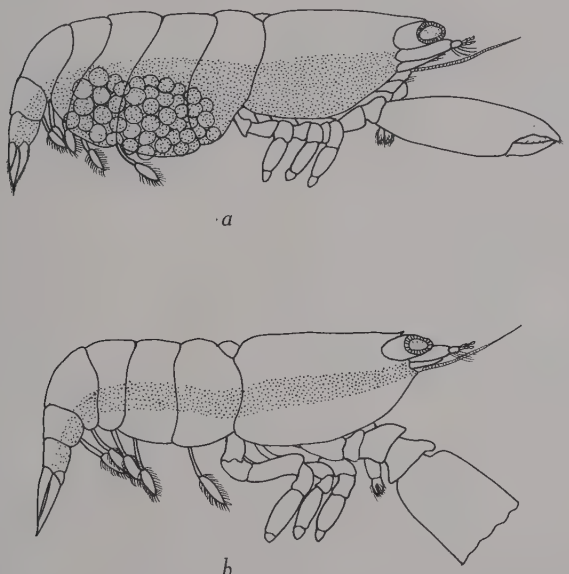

FIGURE 1. *Gnathophylloides minerii* Schmitt. a. Female with eggs. b. Male.

darker pigmented area of the shrimp is exactly the same color as the areas between the spines on the test of the urchin.

In the males the chelae are subequal, the major chela being about two thirds the length of the carapace (Fig. 2a). The fingers are crossed and the fixed finger is curved sharply at the tip. Behind the tip of the fixed finger there is a large forwardly directed tubercle on the inner edge of which is a single small tooth. The tubercle and small tooth are lacking on the minor chela.

In females the chelae are equal and the fingers crossed (Fig. 2b). The tubercle of the fixed finger is so low as to be scarcely perceptible and the tooth is much smaller than in the males.

Ovigerous females were taken from mid-April to the end of August

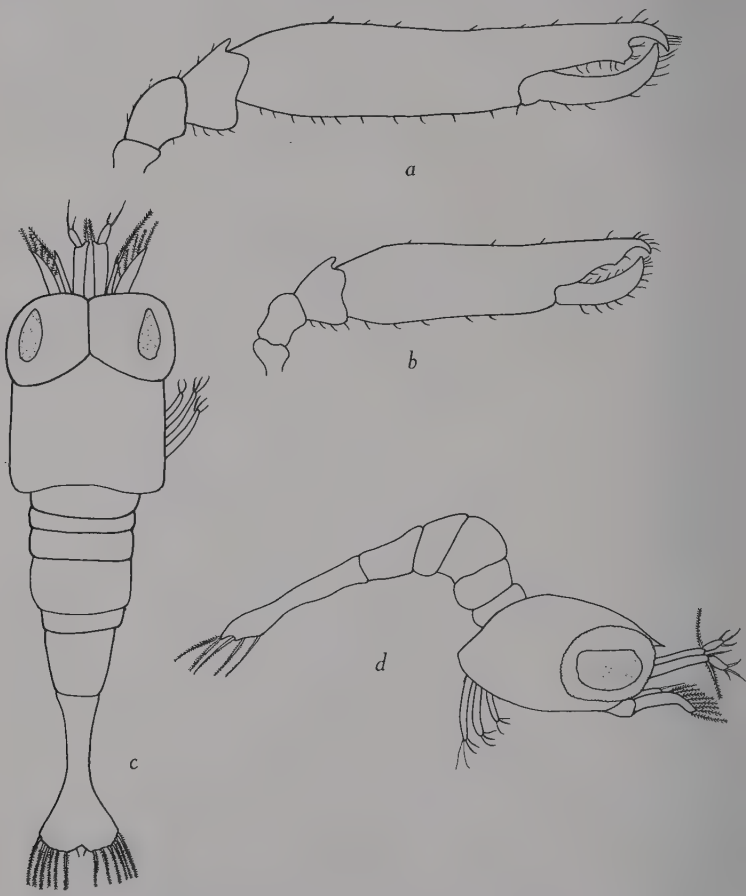

FIGURE 2. a. Left chela of male. b. Left chela of female. c. and d. Larvae.

and larvae were hatched throughout this period. The larvae (Fig. 2c, d) are about 1.7 mm in length when hatched. The carapace is about one third of the length of the whole. The abdomen is sharply flexed. The eyes are large, about equal to one third of the length of the carapace and their lower half is darkly pigmented. The telson is roughly in the shape of an equilateral triangle and has a small notch

in the mid-line. It bears six pairs of terminal spines of equal length and there is a smaller pair on either side of the median notch.

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A TENTATIVE METHOD FOR THE PREDICTION OF THE FLORIDA RED TIDE OUTBREAKS[1]

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ABSTRACT

Terrigenous nutrient supply in a mass of water of estuarine origin as a significant parameter in Red Tide outbreak is further studied. A relationship between an estuarine mass, carrying the nutrient supply, and the ambient environment is suggested. This relationship is applied to the Florida Red Tide with the help of a new hypothesis of Red Tide outbreak.

INTRODUCTION

The logical sequence in the development of scientific control of natural phenomena is observation followed by understanding and then prediction. These orderly steps applied to the problem of Red Tide are far from completion and thus science is not yet in a position to predict with accuracy. But the urgency of the problem has made it desirable to approach the prediction task more directly and empirically.

Successful prediction is likely when all significant parameters are taken into consideration in their proper relationship. Terrigenous nutrient supply has been suggested by Ketchum and Keen (1948) and Gunter et al. (1948) as a significant parameter in Red Tide outbreaks. Kierstead and Slobodkin (1953), in following up this suggestion, considered that the maintenance of a plankton bloom is dependent upon the size of estuarine water mass carrying the supply of terrigenous nutrients. As a preliminary to formulating a method of Red Tide prediction in terms of available meteorological and hydrological data, the treatment of Kierstead is discarded and a relationship between the geometric shape of the estuarine mass and the ambient phenomena is developed which could be used for the purpose.

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Plankton bloom and estuarine water mass

In treating the problem of plankton bloom in relation to the size of estuarine water mass, Kierstead et al. considered a water mass of unchanging dimensions and ascribed the maintenance of a plankton bloom in it to an excess of plankton growth over the plankton loss by diffusion through the water mass boundary. A serious shortcoming of this treatment is the unrealistic assumption that, while diffusion works to deplete the plankton stock, it does not work to reduce the size of the estuarine water mass supposedly sustaining the plankton growth.

It is probable that the reduction in volume of a physiologically suitable water mass is at least equally as critical in keeping the plankton from blooming as the diffusion loss through the boundary of the water mass whose volume remains constant. If the rate of increase of population, N, is described by $(1/N)\ (dN/dt) = k$, where k is the growth rate per population unit, then when k is constant (presumed to hold where the volume is unchanged) the population grows exponentially with time. However, when the physiologically suitable water mass is reduced in size by eddy diffusion, k will not remain constant since there will be a decrease in the total supply of nutrients available. It seems plausible that, as the effects of diffusion on nutrient supply accumulate with time, k will decrease with time. Hence it is clear that plankton bloom is less likely under the circumstance of a constant diffusion drain on a population stock whose rate of reproduction decreases with time.

The dissipation of the estuarine volume in the open sea is generally thought to be the result of eddy diffusion. The rate of diffusion, however, is not constant over all ranges of volume. Nor is it constant over all geometric shapes of estuarine water masses of the same total volume. This may be understood in terms of the stirring and "mixing" (molecular transfer) phases of Eckart (1948). The stirring phase, during which concentration gradient and interfacial area are increased to accelerate the "mixing" phase, is dependent on the turbulent character of ocean currents. Turbulence of many sizes exist, leading to the existence of stirrings of many intensities. For example, a body of estuarine water spread extensively in the horizontal directions is stirred more intensely because more turbulence is acting on it. The degree of preservation of an estuarine water mass in the open sea is thus seen to depend on the geometric shape as well as on the volume of the mass.

Horizontal extent of estuarine mass in open sea

An estuarine water mass, because of its relatively lower salinity, is generally lighter than that of the open sea. In the absence of motion, the estuarine water mass will lie horizontally on the sea. There is, however, always differential motion in the sea and the shape of the

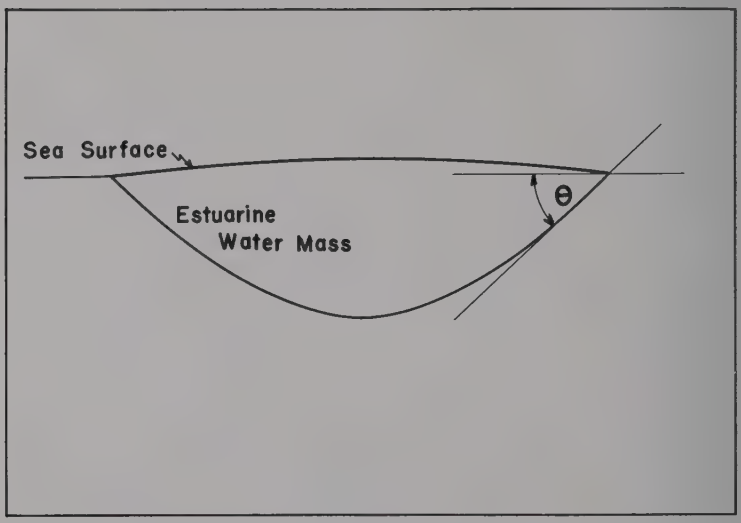

Figure 1. A schematic cross section of an estuarine lens.

estuarine water mass generally takes on a lens form. See Figure 1. Margules' equation for the case of geostrophic motion may be used to estimate the inclination to the horizontal of the lens surface separating the estuarine mass from that of the sea water; this is justified in the absence of better understanding and since qualitative results are still useful. One form of this equation may be written as,

$$\tan \theta = f\bar{r}\ (v_1 - v_2)/g(r_1 - r_2) \qquad (1)$$

where θ is the angle of the discontinuity surface made with the horizontal

f is the Coriolis parameter
$\bar{r}$ is the mean density of the two water masses
r_1 is the density of the sea water
r_2 is the density of the estuarine water
g is the acceleration of gravity

and v_1,v_2 the velocities of sea and estuarine masses respectively.

For the restricted range of actual salinity and temperature involved, the density, r, near the sea surface may be approximated as $r = nS/T$, where n is a proportionality constant, S is salinity and T is temperature of the water. It follows that $(r_1 - r_2)$ equals $n\ (S_1T_2 - S_2T_1)/T_1T_2$ where the subscript 1 refers to sea water and 2 to estuarine water. For a given current shear, the angle θ is inversely proportional to $(S_1T_2 - S_2T_1)$. And if the ratio (S_2/S_1) is constant, say equal to 0.98, then $(S_1T_2 - S_2T_1) = (T_2 - 0.98T_1)S_1$, written as $(T_2 - T_1)S_1$ hereafter for convenience. Since S_1 is the salinity of the sea water and hence relatively constant, it is clear that the warmer the estuarine mass with respect to the sea, the greater the horizontal spread of the estuarine water.

Horizontal diffusion and the relative preservation of estuarine mass in relation to temperature difference

Eddy diffusion in the sea is imperfectly understood; but it is generally agreed that as the scale of the phenomenon increases, the horizontal eddy diffusivity, A, increases. Thus Riley (1951) suggests that the average value of A between two points of distance apart x, be proportional, along with other variables, to the square of x. Richardson and Stommel (1948) and Stommel (1949) proposed that the "neighbor diffusivity", analogous to A, be proportional to the 4/3 power of L, the separation between two neighboring diffusing particles. The reason for the increase of the diffusivities with the scale of the phenomenon is clearly stated by Stommel (Ibid): ". . . a regime of turbulent eddies of all sizes is contemplated. The distance between two initially close particles will be changed at first only by the smallest eddies, the effect of the large eddies being simply to transport the pair as a whole while not tending to change their separation. However, when the separation of the two particles is larger, the large eddies, in addition to the small ones, can act to change the separation, so that as the separation is increased the dispersing influence of larger eddies is brought into play."

Assuming that the magnitude of diffusion is indicated by that of A, one can formulate a qualitative notion of the relative preservation of an estuarine mass of varying contrasting temperatures. For large $S_1\ (T_2 - T_1)$, the angle θ is small and hence the estuarine water is more thinly spread over the sea water; in this case, horizontal diffus-

ion is large and the permanence of the estuarine mass is proportionally reduced. For small negative values of S_1 $(T_2—T_1)$, where the estuarine density approaches the sea water density, diffusion is also large since waters of the same density are readily mixed. For large negative values of S_1 $(T_2—T_1)$ the estuarine mass will sink to the bottom and become unavailable for the support of surface growth. It appears that there is an optimal range of S_1 $(T_2—T_1)$, somewhere between the two extremes where diffusion is the least and where the identity of the estuarine water can be maintained the longest. Since S_1 is the salinity of the sea water and hence relatively constant, one is led to the inference that somewhere between the two extremes, there is an optimal range of $(T_2—T_1)$ most conducive to the preservation of the estuarine identity. This optimal range may be analogous to that of the deviation angle from the vertical, in relation to stability, in the case of a pole standing on its end on a level surface. The precarious stability of the pole on its end is rapidly lost when the pole is tilted beyond a certain small angle.

An hypothesis of large scale Red Tide outbreak

An hypothesis of Red Tide outbreak is necessary before the preceding idea can be applied. Chew (1955), in discussing the salient features of the offshore circulation in the Red Tide region, indicated that (1) the Florida west coast estuarine waters from Apalachicola River to the Everglades all participate in the dominant cyclonic circulation offshore, (2) such participation leads to observed freshening of the offshore water and implies mixing of estuarine waters among themselves in appropriate areas and (3) because the flow patterns are essentially alike through depth, convergence is most likely as the water moves from shallow to deeper depth. On the basis of these hydrographic features, it appears that one possible condition for the outbreak of a major Red Tide is the proper compounding of the Florida west coast estuarine waters in the offshore area west and south of Tampa. In this admixture, the Apalachicola runoff is an important integral part because not only is the runoff as large as the sum total of the remaining runoffs west and south to Everglades, but also because it has been observed to contain high total phosphorus outside its estuarine mouth, indicating the possible presence of estuarine elements essential to incubation of a major Red Tide outbreak farther south. Other probable components of this admixture are the estuarine

waters from Tampa Bay and Charlotte Harbor. The last, particularly, has been observed to contain frequent growth of *Gymnodinium brevis,* the accepted causative fatal factor in fish kills. In this compounding process, the relative preservation of the estuarine characteristics of the Apalachicola runoff until compounded is essential. Evidence of such preservation has been reported by Slobodkin (1953) who wrote, "On June 2, 1952 red discoloration of the sea at approximately 84° 30' W. Long. and 28° 30' N. Lat. was found by the U.S. Fish and Wildlife vessel ALASKA. This discoloration was caused by a dense population of a red ciliate . . . The surface salinity at a hydrographic station in the discolored water (33.4‰) was lower than that at surrounding stations (34.99, 35.47, 36.17) . . . the discolored water was approximately 90 miles from the nearest coast." Judging from the reported position, it is very probable that the discolored water was situated within water derived from Apalachicola River runoff.

The degree of preservation of the Apalachicola runoff is effected in part by the convergence as the water flows southward to deeper bottom. But since the convergence mechanism is present at all times, the additional preservation needed for optimal admixture must be effected by another means. It is suggested that the geometric shape of estuarine masses may be responsible for this preservation and thus for Red Tide outbreaks.

An application, a Red Tide index number

The application of the above qualitative ideas to Red Tide prediction is not an easy task, especially since the required measured variables of current shear, water salinity and temperatures are not available. Nevertheless, it appears possible to approximate the trend of salinity contrast by proper runoff combination, trend of current shear by suitable ambient indicators and from consideration of air-sea interaction, the trend of water temperature difference by appropriate air temperatures. The approximation may then be combined in the manner indicated by equation (1) to form a Red Tide index number.

The runoff data used are those of the Apalachicola River at Chattahoochee (or River Junctions) as reported in the Surface Water Supply of U.S.; these data began in 1929. Air temperatures are those reported by U.S. Weather Bureau and its Cooperative Observer Station from Pensacola eastward to Tarpon Springs. All data are monthly means for June, July and August for each year. These months were

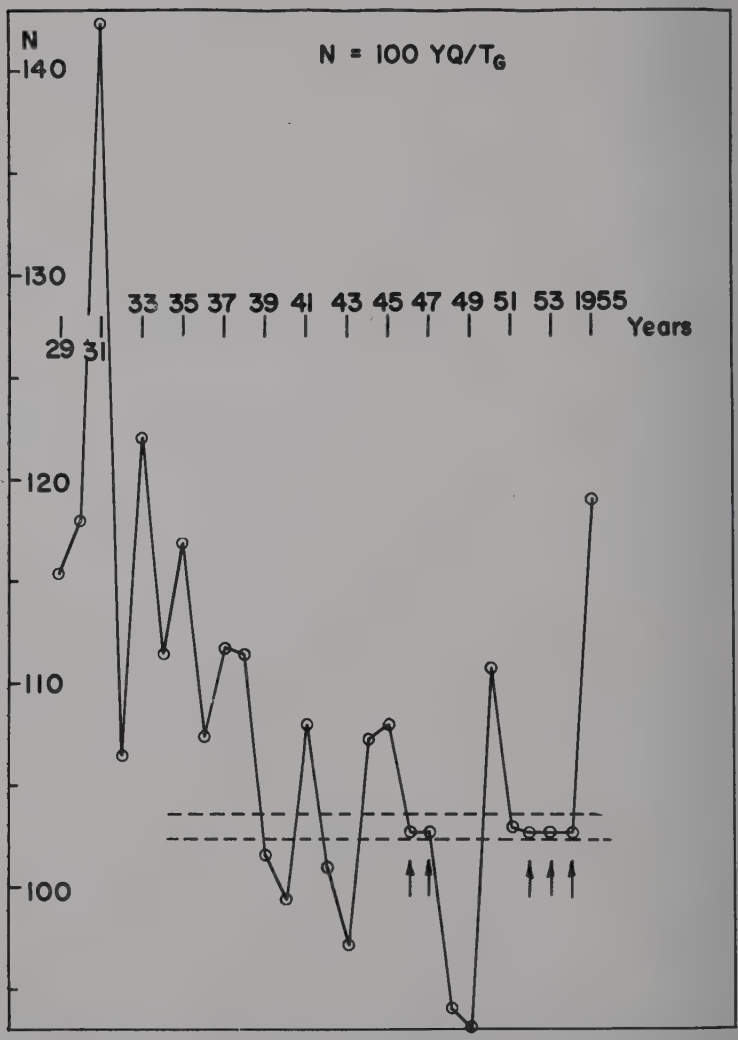

FIGURE 2. Red Tide index number for years 1929-1955. Arrows pointing to years with Red Tide outbreaks.

chosen because the climatological easterlies are most persistent during this season and hence the approximation of the trend of the water temperature difference is more nearly correct.

The basic raw data used in the formation of the Red Tide Index Number are tabulated in Table 1. The abbreviations used are:

T_{20}: Apalachicola mean temperature
T_{11}: Brooksville mean temperature
T_{12}: Carrabelle mean temperature
T_{13}: Cedar Key mean temperature
T_{14}: Panama City mean temperature
T_{15}: Pensacola mean temperature
T_{16}: Tarpon Springs mean temperature
Z : Apalachicola runoff at Chattahoochee or River Junction

Each listed temperature is the arithmetical mean of June, July and August average temperatures. The letter M following some of the tem-

TABLE 1
RUNOFF AND AIR TEMPERATURE DATA FOR JUNE, JULY, AUGUST

Year	T_{20}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	Z
1955	80.20	80.50	79.83	82.30	80.02M	80.50	80.17M	31,262
1954	82.00	81.30	82.13M	84.10	83.50	82.83	81.60	29,900
1953	80.97	80.67	81.23M	81.77	82.27	82.00	81.63	52,480
1952	81.80	80.77	82.07	83.93M	83.47	83.10	82.87	36,060
1951	81.57	80.87	80.83	82.80	83.10	82.83	82.17M	27,597
1950	81.03	80.27M	80.83	82.03	81.83	81.20	82.33M	39,460
1949	80.67	79.53	81.37	80.50	81.83	81.30	——	77,850
1948	80.33	80.40	80.20	82.10	82.17	81.63	80.80	84,640
1947	80.07	79.40	79.97	79.23	82.03	80.87	81.23	62,110
1946	80.20	79.43	80.17	82.00	81.13	80.20	81.27	72,430
1945	81.00	80.27	80.67	82.80	81.40	81.50	82.00	43,060
1944	80.97	80.83	81.13	83.17	81.37	81.67	——	48,360
1943	81.80	80.37	82.37	83.63	82.73	83.00	——	49,520
1942	81.87	81.63	81.47M	84.47	81.03	81.30	83.37	54,030
1941	81.60	81.50	——	82.20	81.80	81.57	81.93	32,248
1940	81.40	81.30	80.77M	82.03	81.20	80.47	81.90	59,770
1939	80.73	80.67	80.77M	81.77	79.77	79.67	79.57	65,210
1938	80.73	80.27	81.27M	81.43	80.60	80.40	81.60	50,510
1937	81.27	80.23	81.40	83.47	80.67	80.20	82.20	47,620
1936	81.00	80.40	80.43	84.10	80.87	80.73	81.17	51,490
1935	81.10	81.77	80.40	82.00	81.33	80.07	81.33	31,625
1934	81.20	81.40	81.40	82.13	82.23	80.50	81.50	49.300
1933	80.87	81.60	81.43	81.93	81.57	79.80	81.73	40,400
1932	81.77	80.20	82.20	82.77	82.67	81.07	83.13	47,700
1931	80.70	81.73	——	83.27	81.63	79.50	82.87	29,510
1930	80.30	80.90	79.60	79.77	——	79.90	81.40	37,400
1929	79.60	81.23	79.80	80.13M	79.57	79.80	81.40	59,000

peratures denotes less than ten days of missing observation. These were included in the computation. The dash denotes more than ten days of missing data and were not used. The Apalachicola runoffs are the sum of the mean June, July and August discharges in units of second-feet (i.e., ft^3/sec).

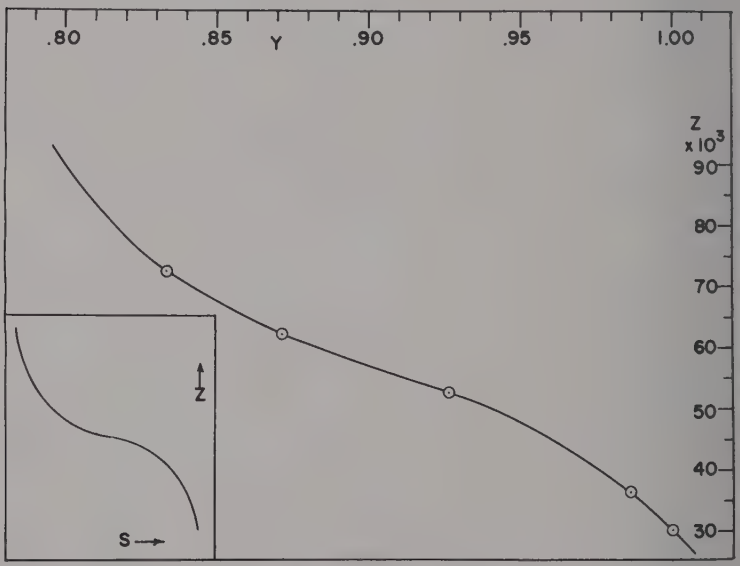

FIGURE 3. Runoffs and the Y factor.

The basis for the Index Number is equation (1).
When $r = nS/T$ and $(S_2/S_1) = 0.98$,

$$\tan \theta = \frac{f\,(\bar{S}/\bar{T})\,(v_1 - v_2)}{(g/T_1T_2)\,S_1\,(T_2 - .98T_1)} \qquad (2)$$

The significant factor in (2) is considered to be

$$W = \bar{S}\,(v_1 - v_2)\,/\,(T_2 - 0.98T_1) \qquad (3)$$

from which the Red Tide Index Number is formed when the trends of the temperature and current shear are inserted. By definition, the temperature trend, T_G, is

$$T_G = 10 + (T_2 - 0.98T_1) \qquad (4)$$

the current shear trend, Q, is

$$Q = 94 - T_{20} \qquad (5)$$

while Y represents the effect of the Apalachicola runoff, Z, on the average salinity $\bar{S}$. T_2 and T_1 are in turn defined by the following:

$$T_2 = (1/3)\ (T_{20} + 2T_{15}) \quad (6)$$

$$T_1 = (1/7)\ (T_{11} + 2T_{12} + T_{13} + T_{14} + T_{15} + T_{16}) \quad (7)$$

Finally, the Red Tide Index Number, N, is defined as

$$N = 100\ (YQ/T_G) \quad (8)$$

Equations (5) and (6) are arbitrary, but necessarily so since the cited principles give guidance only as to the approach and not as to details. In (5), suppose the fluctuation of the current shear in the region is caused primarily by a combination of thermodynamic forces in the water and wind stresses on the water surface, then the deviation of the Apalachicola temperature from a standard may reflect changes in the trends of these forces. The inclusion of T_{15} in (6) instead of T_{14} or T_{12} is based on the relative exposure to the southeasterly wind regime prevailing during this period. The water fetch of the southeasterlies reaching Carrabelle is relatively short,

TABLE 2

COMPUTED PARAMETERS

Year	T_2	T_1	$0.98T_1$	TG	Q	Q/TG	Y-factor	N
1955	80.40	80.45	78.84	11.56	13.80	1.194	0.997	119.0
1954	82.55	82.51	80.86	11.69	12.00	1.027	1.000	102.7
1953	81.66	81.54	79.91	11.75	13.03	1.109	0.926	102.7
1952	82.67	82.61	80.96	11.71	12.20	1.042	0.986	102.7
1951	82.41	81.92	80.28	12.13	12.43	1.025	1.004	102.9
1950	81.14	81.33	79.70	11.44	12.97	1.134	0.977	110.8
1949	81.09	80.98	79.36	11.73	13.33	1.136	0.820	93.2
1948	81.20	81.07	79.45	11.75	13.67	1.163	0.808	94.0
1947	80.60	80.39	78.78	11.82	13.93	1.179	0.871	102.7
1946	80.20	80.62	79.01	11.19	13.80	1.233	0.833	102.7
1945	81.33	81.33	79.70	11.63	13.00	1.118	0.966	108.0
1944	81.44	81.55	79.92	11.52	13.03	1.131	0.948	107.2
1943	82.60	82.41	80.76	11.84	12.20	1.030	0.943	97.1
1942	81.49	82.11	80.47	11.02	12.13	1.101	0.916	100.9
1941	81.58	81.80	80.16	11.42	12.40	1.086	0.995	108.1
1940	80.78	81.21	79.59	11.19	12.60	1.126	0.883	99.4
1939	80.02	80.43	78.82	11.20	13.27	1.185	0.857	101.6
1938	80.51	80.98	79.36	11.15	13.27	1.190	0.937	111.5
1937	80.56	81.37	79.74	10.82	12.37	1.177	0.950	111.8
1936	80.82	81.16	79.54	11.28	13.00	1.152	0.932	107.4
1935	80.41	81.04	79.42	10.99	12.90	1.174	0.996	116.9
1934	80.73	81.51	79.88	10.85	12.80	1.180	0.943	111.3
1933	80.16	81.36	79.73	10.43	13.13	1.259	0.974	122.6
1932	81.30	82.03	80.39	10.91	12.23	1.121	0.950	106.5
1931	79.90	81.80	80.16	9.34	13.30	1.424	1.000	142.4
1930	80.03	80.20	78.60	11.43	13.70	1.199	0.983	117.9
1929	79.73	80.25	78.65	11.08	14.40	1.300	0.887	115.3

while the wind fetch to Panama City includes a portion over land; that for Pensacola is the longest and includes a water fetch north of Cape San Blas.

Table 2 shows the stepwise computation of the Index Number. The Y factor is obtained from an empirical relation between (Q/T_G), Z and the presumptive expectation that N for the Red Tide years should have similar magnitudes. The determination of Y is guided by the consideration that $\bar{S}$ is not measurably affected by a range of low runoff and that $\bar{S}$ approaches a minimal value for a range of the large runoff usually encountered. This is schematically illustrated in the inset of Fig. 3. The final Y-$\bar{S}$ relation is depicted in Fig. 3, where Y is given along the abscissa and expressed as percentage of $\bar{S}$. The five points in the Figure correspond to the Red Tide years; they are determined by Z and Y needed to make N identical for these five years. A smooth curve is drawn through all these points and the extrapolation is made following the trend in the inset of Figure 3. Values of Y for other years are obtained by entering Figure 3 with the appropriate Z and then reading Y off the abscissa. It is encouraging that the curves of Figure 3 and the pertinent portion of its inset are of the same type.

A plot of the Red Tide index against years is given in Figure 2. In this twenty-six year period (excluding 1955), there are two series of authenticated Red Tide outbreaks; these are marked in the Figure. As formulated, though the index number varies irregularly with time, years of Red Tide outbreaks do not coincide with extreme values of the parameter, apparently in agreement with the postulated existence of an optimal range of $(T_2 - T_1)$ for maximum preservation of estuarine integrity. This appears significant, at least to the extent that it has been possible to construct from plausible physical grounds an index that does so. In this sense, the graph in Figure 2 does not constitute a hindcast since none of the data was used as control.

From the nature of the index construction, it is possible to set up a range of index numbers such that all indices corresponding to Red Tide years fall within this range. This range is assumed to be relatively narrow, reflecting the presumed analogy to the stability of a pole on its end referred to above. When so set up, as in Figure 2, one sees that out of the six years with indices inside the range, five had authenticated Red Tide outbreaks, while none of the twenty years outside the range was stained with Red Tide record. It seems

permissible to call this range, the range of maximum Red Tide likelihood or the Red Tide range.

On the basis that the significant parameters in a major Red Tide outbreak are included in equation (8) and that the Red Tide range is properly determined, one may interpret the index as a Red Tide predictor. The required raw data are available in early September; the corresponding forecast period may be taken as the following twelve months starting with October, the month of most frequent beginnings of past series of Red Tide outbreaks. However, one must be cautious, for the index presumably gives merely the probability of a major outbreak on the assumption that the Apalachicola runoff is of significance. Other outbreaks may occur locally and independently. (The index for 1955-56 has been entered in Figure 2 showing that the probability for an occurrence of a major Red Tide from October 1955 to September 1956 is small. This forecast, based on equivalent parameters, was orally communicated on 29 September 1955 to Messrs. E. Mitts and R. M. Ingle, respectively Director and Ass't Director of the Florida State Board of Conservation.)

Discussion and Summary

The importance of terrigenous influence in Red Tide outbreaks has long been postulated and many attempts at a correlation between rainfall and runoff magnitudes and Red Tide incidents have failed. It is likely, therefore, that the efficacy of an estuarine runoff as a possible incubating environ for the growth of Red Tide organisms is not satisfactorily measured by its runoff volume alone. The efficacy may be measured, in part, by the intensity of the convergence mechanism suggested earlier by Chew (op. cit.), by the parameters of temperature and runoff suggested here and possibly by still other as yet unknown variables, though the direct effects of solar and lunar tides may be apparently ruled out because of the noncyclic nature of reported Red Tide outbreaks.

It is suggested that for a given volume of estuarine mass the geometric shape of the mass is an important factor in the conservation of the estuarine characteristics in the open sea. This relation is applied to the Apalachicola River runoff on the hypothesis that the estuarine conservation is necessary to provide the proper incubating environs into which *Gymnodinium brevis* may be seeded from sources at Boca Grande Pass or the Ten Thousand Island areas. A Red Tide index is formed from runoff and temperature parameters;

the result is encouraging. It should be noted that this hypothesis of Red Tide outbreak is but one of many and is not intended as an exclusive mechanism. Finally, the application was made partly to suggest how an hypothesis, woven from observed significant oceanographic features, may be interpreted to make use of available recorded ambient data and partly to underline the desirability of long term observations of significant variables.

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SEA GRASSES OF THE NORTHERN GULF COAST

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Abstract

On the basis of observations in Mississippi Sound and elsewhere, it is known that at least five species of marine monocotyledonous plants commonly known as "sea grasses" occur in abundance along the northern Gulf coast and may be virtually continuous between Florida and Aransas, Texas. An annotated list of species and key are included.

Introduction

Because it is usually assumed that marine spermatophytes, commonly know as "sea grasses," are rare along the northern coast of the Gulf of Mexico between Bay County, Florida, and Aransas County, Texas (Thorne, 1954), it seems worthwhile to record certain observations made in Mississippi Sound while the writer was in residence at the Gulf Coast Research Laboratory, Ocean Springs, Mississippi, during summer months from 1950 to 1955. Additional observations made in the Alligator Harbor area, Franklin County, Florida, and elsewhere are included.

Grateful acknowledgment for the opportunity to work at the Gulf Coast Research Laboratory is made to Dr. R. L. Caylor, founder and first director.

Annotated List of Species

The following annotated list deals with five species of sea grasses that occur in abundance in Mississippi Sound, and a sixth that is to be expected outside the barrier islands at depths ranging from 15 to 50 feet.

Ruppia maritima L., widgeon grass, the only species previously known to be abundant in Mississippi Sound, occurs principally along the mainland shore, especially in bayous where the salinity is usually less than half that of inshore Gulf waters.

Thalassia testudinum König is apparently the most abundant of any of the sea grasses in Mississippi Sound. It occurs along the inside of the barrier islands extending from depths of 1.5 to 2 feet along the beaches, outwards to depths of 8 feet or more, with occasional interruptions. It also occurs in patches or bands along the outer beaches of the barrier islands, where the inner edge of the growth is in deeper

water than in the sounds and bays. The outer or deeper edge of *Thalassia* beds is evidently determined primarily by light penetration and thus it occurs in deeper water outside the barrier islands than in the sounds. Apparently this species has not been reported to occur between Florida and Aransas Pass.

Cymodocea manatorum Ascherson (*Syringodium filiforme* Kützing), manatee grass, grows interspersed with *Thalassia,* usually in lesser abundance than *Thalassia.* It was not found in pure stands. In general, it occurs farther out from the beach than does *Thalassia.* Its relative abundance is easily underestimated because of its filiform leaves.

Diplanthera wrightii (Ascherson) Ascherson (*Halodule wrightii* Ascherson) occurs in interrupted patches along the inner beaches of the barrier islands, and probably along the outer beaches also. It grows in pure stands closer to the beach than any other species. Evidently it will tolerate higher water temperatures and longer exposure to the air than the others. Beds of *Diplanthera* are sometimes higher than the surrounding sand, indicating that it has a tendency to hold or accumulate sand. Farther out it is sometimes interspersed with *Thalassia* where the development of *Thalassia* is subnormal. In areas of vigorous development of *Thalassia* and *Cymodocea, Diplanthera* is usually absent. Apparently it has not been reported previously between Tampa Bay, Florida, and Aransas, Texas.

Halophila engelmannii Ascherson seems to be the least abundant of the five species. It has been found only within beds of *Thalassia* or of *Thalassia* and *Cymodocea.* Though inconspicuous because of the taller leaves of its two associates, it is often present in abundance. It can best be observed by means of suitable air-supplied diving equipment which permits the observer to glide horizontally over the sea grass beds and to brush aside the taller leaves of *Thalassia* and *Cymodocea.* Since it grows partially shaded by the other sea grasses, it evidently tolerates lower light intensity and hence may be expected to occur in deeper water. Taylor (1928) obtained *Halophila* by dredge at a depth of over 220 feet at Dry Tortugas, while his shallowest record was about 14 feet. In all areas observed by the writer, *Halophila* occurs within a foot of the shallowest location of *Thalassia.*

Apparently this species also has not been reported previously between Tampa Bay and Aransas, Texas.

Halophila baillonis Ascherson, although apparently not reported previously north of Dry Tortugas in the Gulf, has been collected re-

peatedly by dredge and aqua-lung in 20-30 feet of water 10 to 12 miles southeast of Alligator Point in the open Gulf. It has also been taken by dredge at similar depths off Pensacola. It seems highly probable that this species occurs also at many localities along the northern Gulf coast between Florida and Texas and it may be almost continuous. Because it evidently occurs at greater depths than any of the other species listed here, collecting it is difficult and usually accidental. Taylor (1928) dredged it from about 16 to 90 feet at Dry Tortugas. In its northern range it seems to be confined to depths exceeding 20 or 25 feet.

Discussion

There is reason to believe that the distribution of *Thalassia, Cymodocea, Diplanthera,* and two species of *Halophila* is essentially continuous around the entire Gulf coast. There is little doubt as to their abundance without major interruption between the Florida west coast and Mississippi Sound. Off St. Marks Light, Wakulla County, Florida, there are literally square miles of bottom that are completely covered with mixed stands of *Thalassia, Cymodocea,* and *Halophila engelmannii* from a depth of about two feet to 15 feet or more. Outside these beds *Halophila baillonis* occurs. The bottom of Alligator Harbor, Franklin County, is almost entirely covered with the same species and there are patches of *Diplanthera* in addition.

Shifting sands and river mouths are the two major factors responsible for minor interruptions in the distribution of sea grasses. South Shoals is a ridge of shifting sand that extends from the beach at Alligator Point seaward for a distance of about seven miles. Even in this area there are scattered patches of sea grasses. Larger interruptions may occur opposite mouths of major rivers but because of the remarkably gentle slope and the resultant width of the continental shelf in the northern Gulf, sea grasses are able to grow many miles off shore where salinities remain sufficiently high despite the rivers. Furthermore, there is usually a tongue of high salinity water beneath river effluent that extends much nearer shore than might be expected.

In general the outer edge of sea grass beds seems to be determined by light penetration, whereas the inner edge seems to be determined by wave action and shifting sands or, in some places, by the level of extreme low tides. Sea grasses are often exposed at spring low tides, after which a killing of the leaves is evident.

The importance of sea grasses as basic producers along the Gulf coast cannot be over-emphasized, as has been pointed out by Voss

and Voss (1955). They published a map showing the distribution of *Thalassia* around the Florida coast with the exception of western Florida. It is clearly evident that the attached marine algae are responsible for but a small fraction of the productivity carried on by the sea grasses in the Gulf. Many ecological problems of these important plants await study.

Key to the Sea Grasses of the Gulf of Mexico

In order to encourage further observations on the distribution of sea grasses in the Gulf of Mexico, a key to the six species discussed herein is included. Only *Ruppia* may be expected in water of low salinity and even in fresh water. The others are more stenohaline and probably do not occur where salinities fall much below 25% for considerable periods of time.

1. Leaves flat, of the same width throughout 2
   Leaves terete or, if flat, widest at or above the middle 4
2. Width 5 to 10 mm ..... *Thalassia testudinum*
   Width 1 to 2 mm 3
3. Leaves 1-1½ mm wide, the tip with a single point, an expansion at the base; stems often in part upright and above the bottom .. *Ruppia maritima*
   Leaves usually 1½-2 mm wide, no expansion at base but with ligulate sheath, leaf tips with 2 or 3 points; stems horizontal, covered by bottom material except where exposed by erosion ..... *Diplanthera wrightii*
4. Leaves terete, about 2 mm in diameter ..... *Cymodocea manatorum*
   Leaves flat, widest near or above the middle 5
5. Leaves in pairs at each node ..... *Halophila baillonis*
   Leaves in a whorl of 4 to 8 at the tip of a short erect stem..... *Halophila engelmannii*

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COELENTERATE NEMATOCYSTS AS A CAUSE OF CERTAIN KINDS OF SEA STINGS[1]

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Abstract

At least two kinds of irritation arise from contact of man's skin with minute planktonic organisms in southern Atlantic waters off the U.S.A. One kind, called sea-bather's eruption, affects beach bathers and has been associated with marine schistosome cercariae by some workers. Another is commonly experienced by swimmers in reef areas. Evidence which suggests that the latter kind of irritation is caused by the nematocysts of larvae, small adults or parts of the Coelenterata is presented.

Introduction

Periodically, swimmers off the southeastern coast of Florida complain of being stung by invisible sea creatures, popularly termed "sea lice." There are at least two types of reaction to these stings. One, sea-bather's eruption, is experienced by beach bathers and has received considerable public attention and scientific investigation. This is an acute form of dermatitis (Sams, 1949) which, in the opinion of Hutton (1952), is probably caused by marine schistosome cercariae. Leigh (1955) summarized records of marine cercariae known either experimentally or naturally to cause dermatitis in man and described another, *Gigantobilharzia huttoni* (Leigh, 1953). However, because sea bather's eruption almost always occurs on parts of the body under the bathing suit in contrast to a more general distribution in known cases of fresh-water and marine cercarial dermatitis, Leigh (1955) suggested, ". . . caution in associating the Florida eruption with schistosome cercariae at this time." Thus no fully satisfactory explanation of the cause of the dermatitis has yet been made, and Dr. W. H. Leigh of the University of Miami Zoology Department is at present engaged in further studies of that problem.

Another type of reaction, familiar to marine collectors and skin divers who swim in the vicinity of the reefs from the Palm Beach area to Key West, is probably not due to the same causative agent(s) as sea-bather's eruption. It is with this reaction and the organisms which may cause it that the writer is particularly concerned.

According to Mr. Eugene Shinn, an experienced skin-diver, and others, offshore "sea lice" occur sporadically from May to September,

[1]Contribution No. 166 from The Marine Laboratory, University of Miami.

June being the month when they are usually most prevalent. They are patchy in distribution and, in calm water, seem to be confined to the surface since the swimmers generally do not experience stinging when they dive. Mr. Shinn also associates this type of "sea lice" with clear oceanic water and says that they can be avoided by moving inshore to the less translucent coastal water.

Referring to sea-bather's eruption, Hutton (*loc. cit.*) stated, "In some cases, there is a slight pricking while the bather is still in the water, but in most cases, discomfort is not noticed until leaving the water." Conversely, the offshore "sea lice" cause an immediate sharp stinging sensation, so severe that skin-divers call water containing them "hot water." Sometimes, the irritation produced by the sting disappears in a few minutes and there is no after-effect. At other times, a weal, consisting of a raised white area around a red spot, appears at once. Later this may become pustulous. With this type of sting, itching may not begin for six to 10 hours. The weals may last a week, but usually they disappear within three days.

Deeply sun-burned, toughened skin is either least affected or not at all, according to Shinn. Face and lips, throat, axillae and the undersides of arms are affected. The area covered by the bathing suit is affected in addition to the tender, exposed portions of the body, unless the suit fits tightly, in which case it affords protection from the organisms. As noted earlier, sea-bather's eruption is usually confined to the parts of the body under the suit.

Hutton's (*loc. cit.*) experiments to find the cause of sea-bather's eruption ruled out many common planktonic forms (spiny or toxic plants, protozoans, polychaete larvae, crustaceans, etc.) as capable of producing any such reaction in man, and certainly there have been no clear indications that cercariae are the off-shore "sea lice." The discrete nature of the sting at least defines the organisms as being of a kind which, however small, possesses a mechanism powerful enough to penetrate a man's skin. Dr. G. L. Voss of the University of Miami Marine Laboratory, the writer, and other marine biologists have long believed that this type of sea sting is caused by minute planktonic coelenterates or parts of coelenterates or both. The results of the stings are similar to the results of contact with large adult coelenterates, such as the Portuguese man o' war *(Physalia physalis),* stinging coral *(Millepora alcicornis)* and certain scyphozoan jellyfish. Of course, in the latter case, the effects are comparatively massive

because of the batteries of nematocysts which arm the numerous tentacles and often other parts of the body as well. Samples taken from patches of "hot water" have provided some evidence, presented in the following paragraphs, to support this view.

Observations

While swimming off Tennessee Reef on May 31, 1955, Mr. Shinn encountered an extensive area of "hot water" and collected a quart of it. The water contained a large amount of the blue-green alga *Skujaella Thiebautii* (considered characteristic of "hot water" by some skin-divers because of its great abundance in coastal waters during summer months), diatoms, protozoans, polychaete larvae, gastropod veligers, copepods, one holothurian larva, and planulae which, excepting the protozoans, were the most abundant animals present. The writer did not examine the water until about 24 hours after it was collected; by then, many of the planulae had died. However, approximately 75 were removed from the upper half of the quart jar, and, based on the one sample, an estimate of 100 planulae per liter of sea water is reasonable.

Most of the time, the planulae were roughly triangular, being broadly truncate at one end and bluntly rounded at the other, with a depression in the center of the broad end; at times, however, the shape suddenly changed to spherical. Short cilia of approximately equal length were distributed over the ectoderm. The planulae showed no behavioral anterior-posterior differentiation, for either end could be anterior in swimming. In greatest dimension, they measured from 0.2 to 0.5 mm.

It was particularly interesting to find that numerous, fully-developed nematocysts were almost evenly distributed through the outer part of the ectoderm. These large nematocysts were stenoteles or penetrants, found only in members of the Class Hydrozoa and within the Class, limited to tubularian hydroids (Athecata), the Milleporina and the Siphonophora (Hyman, 1940). Undischarged stenoteles measured, on the average, 10 x 13 microns. They discharged readily when the animal was stimulated with a needle, when pressure was applied, the salinity of the water increased through evaporation or irritating chemicals such as acetic acid introduced. This kind of nematocyst is adapted for penetration; Hyman (*loc. cit.*) stated that, "'. . . the tube may penetrate for some distance into soft tissues and

can pass through chitinous armor. The capsular contents are ejected from the open end of the tube."

Smaller nematocysts, measuring about 3 x 4 microns, were abundant, especially in the basal portion of the ectoderm. These were not identified because all efforts to force their discharge failed. Possibly they were undeveloped stenoteles and their discharge mechanism had not yet fully formed.

The fact that abundant zoochlorellae, 3 - 4 microns in diameter, were interspersed between the ectoderm cells is relevant to a collection which contained unidentified cell masses, mentioned subsequently. Infection with the symbionts of the parent probably occurred in the ovum; Fraser (1931) described the passage of zooxanthellae from the tissues of the hydroid *Myrionema amboinense* into its ova and cited observations of this process in other hydroids and in *Millepora*.

The larvae were kept in a 60 mm Petri dish and the water was changed every second day. Many were killed in examination and efforts to explode the smaller nematocysts, and some died. Skin tests made twice, with negligible results, were not continued because it was preferred to attempt rearing the few larvae available. The following observations are based on the 10 survivors of June 5, 1955.

By June 5, the planulae had begun to elongate, and on June 8, they were definitely elongate, although still able to vary their shape. At this time, they were from 0.5 to 1.0 mm long, and it is estimated that the increment in length during one week in the laboratory was 0.5 mm. The larger specimens were now oriented so that the broad end was always anterior in swimming. The ectoderm at the anterior end was approximately twice as thick as along the sides of the body and at the posterior end. Formation of the coelenteron was beginning to be apparent through the disappearance of the solid mass of opaque brown entoderm in the posterior quarter of the body. During the next week, the coelenteron of the larger specimens became fully evident, but there was no change in size or activity. The smaller ones continued to grow until they too were about 1.0 mm long.

The larvae showed signs of settling on June 20: they would swim to the bottom of the dish, anterior end first, rest there briefly, leave the bottom and then return to it after a few seconds. Because this behavior seemed to indicate that the substrate was not suitable, small pieces of rough glass were placed in the dish on June 21, and by the next morning, one larva had settled on a piece of glass. This settled larva had a known free-swimming period of 21 days, which probably

was longer than normal owing to laboratory conditions. Stephenson (1931) found that laboratory-reared planulae of the coral *Pocillopora bulbosa* remain free-swimming for periods varying from less than 24 hours to more than a week. A free-swimming life of three days or less has been recorded for certain athecate hydroids (Fraser, 1931).

The larva had fixed itself on a corner of glass and this made observing difficult. On June 22, the body was cylindrical, rounded on top, and about 0.5 mm high, with three widely-spaced stolons extending from the base. It began to decrease in size until, on June 27, it consisted of an unequally bilobed mass, approximately 0.14 high and wide, with slightly longer stolons. By July 5, the stolons had elongated somewhat but the size and shape of the body remained the same. It appeared to be deteriorating. Two planulae were still swimming in the dish; the rest had died without settling. Shortly afterward, observations had to be discontinued.

It was considered that these might have been the planulae of *Millepora alcicornis,* which forms extensive colonies of known virulence on Florida reefs. However, the above observations only show that the planulae were not siphonophorans and that they were the young of either an athecate hydroid or the millepore. In any case, it seems likely that they were the cause of the "hot water" from which they were collected.

Additional collections of water containing "sea lice" are listed below.

1. A 500 cc water sample, Long Reef, Florida, June 21, 1955, E. Shinn, collector. Contents: protozoans, a few copepods, and two planulae.
2. A 15 cc water sample, preserved in a high percentage of alcohol, Delray Beach, Florida, December 20, 1955, Steve Forsyth, collector. Contents: protozoans, naviculate diatoms, *Skujaella Thiebautii,* one small hydroid medusa, several zoaeas, and abundant aggregations of animal cells, which had been broken from their original association, perhaps by the preservative. These cell masses had all the readily visible characteristics of the planulae crushed the previous summer to force discharge of nematocysts. They contained penetrants, smaller nematocysts and algal cells which had not yet lost their bright green color. Loose, undischarged nematocysts were common in the sample.
3. A half-hour plankton tow, preserved in formalin, Elbow Reef,

Florida, July, 1956, E. Shinn, collector. Notable contents: numerous planulae and abundant broken parts of the cormidia of siphonophores. The latter were mostly gastrozooids with tentillae, bearing extensive batteries of nematocysts. The nematocysts of some Siphonophora, in addition to *Physalia,* are known to produce severe reactions in man, but there is little information on which species are capable of it.

Usually, records of the occurrence of "sea lice" on bathing beaches are kept by the supervisors of those areas. There are no such records for offshore swimming areas, and one generally must depend on the information and samples provided by a few interested skin-divers. It was thus believed worthwhile to present these fragmentary observations in the hope of stimulating investigation. The problem is an interesting one, not from the point of view of prevention, but because it probably would lead to studies of spawning periods and larval forms of local reef-dwelling coelenterates and of the degree of toxicity to man of these forms and the several species of Siphonophora which inhabit outer coastal water.

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RECENT FISH RECORDS FROM PUERTO RICO

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Abstract

This paper brings up to date unpublished records of fishes from Puerto Rico. Distr. and abundance of 108 spp. are discussed. Interesting records are included of fishes which have been previously reported in the literature from Puerto Rico. Seasonal spawning records show periodicity. Several important fish spp. are marked by their absence in the waters in Puerto Rico.

Introduction

The purpose of this paper is to bring up to date the records of fishes from Puerto Rico. The fishes are discussed by family and species in approximate phylogenetic order. Records of 108 species are discussed; most of these records are new in scientific literature in reference to Puerto Rico. The breakdown of the fishes is as follows: 9 sharks, 57 shore fishes, 31 pelagic fishes, and 11 deep water fishes. The total number of fishes now known from Puerto Rico is around 420 species. Many of the fishes discussed herein are in the fish collection of the College of Agriculture and Mechanic Arts, University of Puerto Rico at Mayagüez. The catalog numbers are preceded by UPR-(University of Puerto Rico).

The history of the fish collection started in the Biology department of the College at Mayagüez. The oldest collections were made by Professor Stuart T. Danforth around 1934. Up through 1939, there are additional small but interesting collections by Professor Virgilio Biaggi, Jr., José A. Ramos, Luis A. Costas Grana, and others. From 1942 to 1944, the fish collection was enhanced through the efforts of Ventura Barnés, Jr., who was working at that time as fishery biologist and engineer on an exploratory and developmental fishery survey sponsored by the U. S. Fish and Wildlife Service (whose team was headed by Richard T. Whiteleather) cooperating with the Department of Agriculture and Commerce of Puerto Rico. In the summer of 1951, the collection was substantially increased by Professor Luis R. Rivas of the University of Miami, who was visiting professor in ichthyology.

The author's first connection with this fish collection was in January 1946, when Professor José A. Ramos, head of the Department of Biology, kindly permitted him to look over the fishes in the collection.

On a second visit in May 1946, the author made some preliminary identifications on the Barnés collection at the Fishery Research Laboratory near the College; this Laboratory was then in charge of Mr. Pedro Vergne Roig, fishery economist for the U. S. Fish and Wildlife Service. The author was invited as visiting professor in ichthyology in the summer of 1952, and again from January to July 1954. The collection was further increased and was organized in order of families. By July 1954, nearly 1000 catalog entries were completed with student help. There are about 10,000 specimens in the collection at the present time including numerous uncatalogued fishes. Dr. Biaggi has recently given a course in ichthyology and is continuing care of and making additions to the fish collection.

Acknowledgments

The author wishes to mention in particular the sustained interest and aid over the years of Mr. Félix Iñigo, chief of the Fish and Wildlife Section of the Department of Agriculture and Commerce of Puerto Rico, and Mr. Buenaventura Quiñones Chacón, formerly chief of the same section. The author is indebted to the assistance of professors Ramos, Biaggi, and Pedro J. Soler in respect to work on the fish collection. The facilities of the University's new Marine Laboratory have been given kindly to the author by the Director, Dr. Juan A. Rivero. Valuable assistance in identifications and name changes have been contributed by Dr. Loren P. Woods at the Chicago Natural History Museum, Dr. Leonard P. Schultz and Dr. Isaac Ginsburg at the U. S. National Museum, Mr. John T. Nichols at the American Museum of Natural History, Mr. Clarence L. Smith, Jr., at the University of Michigan and Dr. James E. Böhlke at the Academy of Natural Sciences of Philadelphia.

The author wishes to add that much of the work of this list of fishes has been made possible through his connection with work (supported by the Dingell-Johnson program in Puerto Rico) on a marine sport fishery survey and a survey of the Añasco River with the able assistance of Mr. Herbert A. Zalduondo of the same department—Section of Fishery and Wildlife, Department of Agriculture and Commerce of Puerto Rico.

Notes on Distribution

Although this paper is primarily concerned with new or unpublished

records from Puerto Rico, a few observations on fish abundance and distribution in Puerto Rico water deserve special mention:

Upeneus parvus Poey was "known only from the type, which was obtained by Poey in Cuba, and from a specimen recorded from Puerto Rico by Dr. Alvin Stahl" (Evermann and Marsh 1900, p. 121), until 4 fishes were collected by Barnés in January 1943 from Añasco Bay in a trawl. These four goatfishes are now at the U.S. National Museum.

The myth of the Spanish mackerel, *Scomberomorus maculatus* (Mitchill) occurring in Puerto Rican waters needs clarification. Evermann and Marsh say "rare or unknown in Cuba, but is known from Jamaica and Porto Rico"; it is more likely that the reverse is true. The author has seen hundreds of *Scomberomorus* from Puerto Rico during 1945-46, 1952, and 1954 to 1956; the painted mackerel *Scomberomorus regalis* is abundant more or less all year around and the kingfish *S. cavalla* is less abundant except during the summer months. Not a single Spanish mackerel, *S. maculatus,* has been seen by the author except for Florida Spanish mackerel which are imported frozen from the United States. In Puerto Rico, *S. regalis* is not known to grow larger than 13 lbs.; *S. cavalla* is known to grow over 50 lbs. in local waters and may reach 100 lbs.

The true red snapper, *Lutjanus aya,* is rare in Puerto Rican fish markets. Evermann and Marsh describe a 21-inch fish from Aguadilla; but none have been seen, in spite of frequent visits to Aguadilla fish markets. It is possible that Puerto Rican fishermen do not regularly fish red snapper banks, but they do catch deep water snappers such as *Etelis oculatus, Lutjanus vivanus,* and *Lutjanus buccanella;* thus the absence of red snappers is not explained. Mr. Barnés told the author that he never saw a *L. aya* during his two years of exploratory fishing in Puerto Rican waters.

The mystery of the red snapper is somewhat corroborated by the apparent scarcity of the red grouper *Epinephelus morio* in Puerto Rican waters. The author has seen only 3 small red groupers in two years of checking Puerto Rican market fishes. The Nassau grouper, *E. striatus,* on the other hand, is a closely related species which is abundant and omnipresent in Puerto Rican waters.

The "pargo prieto" or mangrove snapper *Lutjanus griseus* of Puerto Rico apparently grows larger than the 16 to 18 lbs. mentioned in

the literature. On Sept. 10, 1955, a snapper 30½ lbs. and 36 inches T. L. was caught at night off a dock in shallow water at La Parguera. All the colors of the fish were similar to the smaller mangrove snappers, with gray on the back and sides and reddish on the belly. There was no backward projection on the vomer, as is supposed to be characteristic of the mangrove snapper. The author suggests that the backward projection of the vomer which is so clear in smaller mangrove snappers gradually disappears with age. In Puerto Rico, the "pargo prieto" is known by fishermen to grow to over 100 lbs. The possibility that the very large snappers may be the cubera, *Lutjanus cyanopterus,* has been considered, but the 30½ lbs. fish seen by the author is believed to be *L. griseus.*

The "yellow jack", *Caranx bartholomaei* (Cuvier and Valenciennes), is described in three different volumes of fish literature as attaining a length of 15 inches. In Puerto Rico, the yellow jack is known under different names in different localities. At La Parguera, an old fisherman told me it is known as "medregal amarillo" and he has seen them up to 20 lbs. Elsewhere the yellow jack is known as "cojinuda amarilla" (La Parguera), "guaymen amarillo" (Puerto Real, Cabo Rojo), and "chibi amarillo" (Aguadilla).

During 1956, two large yellow jacks were caught by spearfishermen in Puerto Rico. Dr. Thomas Theis, of the Federal Experiment Station at Mayagüez, shot a yellow jack weighing 12 lbs. and measuring 26″ to the fork of the tail; the place was north of Rincón in April (this specimen is now preserved in the collection at the College). In May, Mr. Don Baaska shot a yellow jack at Condado, Santurce, which weighed 16 lbs. 11 oz. and measured 35¼ inches total length with 20½″ girth. The gills of Baaska's fish have been saved; the gill raker count is a total of 15 rakers for each gill arch.

The yellow jack in Puerto Rico seems to be less abundant than the other jacks such as *Caranx ruber, C. crysos, C. latus,* and *C. hippos.* The author using a face mask has observed young yellow jacks of about 3″ in length near the Marine Laboratory dock at Magueyes, La Parguera, in the summer of 1955. Deep yellow color occurs in a wide stripe from the top of the head along the back and whole tail, dorsal, and anal fins; there is light blue on the upper sides and silver on the belly.

The apparent absence of the purple and yellow pseudochromid,

Gramma loreto Poey, and the duller colored *Rhegma* in Puerto Rican waters is perhaps significant as an indication of a faunal paucity eastward in the West Indies. *Gramma* is known from Cuba, the Bahamas, and Bermuda; and the author has collected them at Port Antonio, Jamaica and Petit Gonave Island, Haiti. *Rhegma* is known from Dry Tortugas and Honduras and the author has collected one from Arcadin Islands, Haiti. While both species may yet be collected from Puerto Rico, their absence to date is noteworthy.

Beebe and TeeVan noted the abundance of the coral wrasse, *Halichoeres garnoti,* in 1927 in Port-au-Prince Bay, Haiti. The author noticed the same abundance around Port-au-Prince from August to October 1953. This species, however, is rare in Puerto Rican waters, and is seldom seen on the reefs. Not more than two or three specimens are in the College collection.

With the few exceptions noted, the marine fishes of the West Indies are widely and uniformly distributed. This list further supports the wide distribution of the species by the additional records.

Habitats

The shore habitats of fishes in Puerto Rico may be divided for convenience as follows: (1) Muddy bottoms near river mouths, (2) open sand beaches, (3) coral reefs, and (4) mangrove areas.

(1) *Muddy bottom* areas such as Mayagüez and Añasco have numerous eels such as *Ophichthus, Conger, Kaupichthys,* and Sciaenids such as *Stellifer, Ophioscion,* and *Larimus* are abundant. Snook and tarpon may be abundant but are less limited to this type of environment. At times the anchovy, *Cetengraulis edentulus,* is extremely abundant in muddy bottom bays. In July 1954, the author noted activity of these anchovies on several successive nights. One morning seven of these anchovies were found in the bottom of the rowboat at anchor, on July 7, in Mayagüez Bay.

(2) *Coral reefs* have the greatest variety of fishes. Here, brightly colored fishes such as angelfishes, parrotfishes, and wrasses predominate. Groupers and snappers occur in moderate abundance. The barracuda *Sphyraena barracuda* is a surprisingly common predatory species. Around 90 species of fishes occur more or less regularly in the fish pot ("nasa") fishery of Puerto Rico; fish pots are the chief means of fishing around the island.

(3) *Open sand beaches* around Puerto Rico are usually affected by surf except in calm weather. The only means of fishing these beaches are with haul seines, or large cast nets which are used on the north coast. Small pompano, *Trachinotus,* threadfin *Polynemus,* and sardines *Harengula* are typical of this type of habitat. Where deep water runs close to shore as it does north of Aguadilla, scads such as *Trachurops* and *Decapterus* are caught; at times even frigate mackerel *Auxis* and false albacore *Euthynnus* are seined close to shore.

(4) *Mangrove habitats* occur in many enclosed lagoons such as Joyuda, Aguas Prietas (Fajardo), Jobos, etc. The mangrove snapper, tarpon and snook are found in these waters. Gobies and small eels are numerous. A record of 4 lb. jewfish *Promicrops itaiara* from under a mangrove in Joyuda Lagoon is noteworthy; according to local fishermen, young jewfish are common here. On April 6, 1954, the author and Chris Ahrens seined the young of several species of fishes from the west end of Phosphorescent Bay: young *Lachnolaimus, Archosargus unimaculatus, Ocyurus, Lutjanus,* and parrotfishes were among the fishes collected.

Periodicity in the spawning of marine fishes has been remarked in the records of the author from Puerto Rico. Evidence of spawning activity has been assumed when fishes have been found from which ripe or near ripe eggs or sperm could be pressed out of the genital pore, or when very young fishes have been found. By months the following fishes have been noted in spawning condition by the author in Puerto Rico:

JANUARY: *Epinephelus guttatus, Upeneus maculatus.*

FEBRUARY: *Archosargus unimaculatus* (heavy run of spawning fishes seen at La Parguera on Feb. 16, 1954), *Spheroides testudineus, Mycteroperca bonaci* (ripe male from St. Eustatius on Feb. 17, 1946).

MARCH: *Hemiramphus brasiliensis, Gerres cinereus, Upeneus martinicus, Ocyurus chrysurus, Bathystoma aurolineatum, Haemulon plumieri, Anchovia choerostoma.*

APRIL: *Upeneus martinicus, Oostethus lineatus, Scomberomorus regalis, Makaira albida* (well formed eggs in ovaries reported).

MAY: *Euleptorhamphus velox, Scomberomorus regalis, Caranx crysos, Caranx hippos, Rhombochirus osteochir, Parexocoetus brachypterus, Chromis marginatus.*

JUNE: *Gerres cinereus, Caranx latus, Haemulon macrostomum,*

Dinematichthys cayorum (with young fishes in ovaries), *Makaira albida* (section of ovary preserved).

JULY: *Corvula sanctaeluciae, Scomberomorus regalis, Euthynnus alletteratus, Atherina stipes, Atherina araea, Anchovia brownii, Haemulon macrostomum.*

AUGUST: *Scomberomorus cavalla, Eques punctatus.*

SEPTEMBER: *Pomacentrus leucostictus.*

OCTOBER: *Labrisomus nuchipinnis* (female swollen with near ripe eggs).

NOVEMBER: *Gobionellus boleosoma* (males with bright red breeding colors).

DECEMBER: *Sicydium plumieri* (large collection of transparent young "seti" from mouth of Arecibo River by Barnés, Dec. 12, 1941). *Cephalopholis fulvus.*

The above notes contain significant data on only 34 species which is barely a start. With the possible exception of *Gerres cinereus* which seems to have a rather protracted breeding season, most of the species are found in breeding condition only during a more or less limited period of the year.

The barracuda, *Sphyraena barracuda,* is rather secretive about its breeding habits. No ripe gonads have yet been seen by the author. Young of one to two inches in length have been noted from June through October, which indicates a rather prolonged summer spawning season.

FAUNAL LIST

Family CARCHARHINIDAE. Ground sharks or "tiburones"

1. *Carcharhinus acronotus* (Poey)

This shark is characterized by the deeply notched outer edges of the upper teeth. The first specimen was seen at La Parguera in June 1954. It was a male 40″ T. L. with claspers 4″ long. Several more have been seen since. The head of a small specimen has been preserved.

2. *Pterolamniops longimanus* (Poey)

The white tipped shark is characterized by a white patch on the top of the first dorsal fin. The tips of both the first dorsal and the pectorals are broadly rounded. The tip of the anal fin reaches to the origin of the caudal fin. A female 7′ T.L. and about 140 lbs. was caught trolling north of Desecheo Island on Oct. 9, 1955. One or two have been seen by the author since then. This species is prob-

ably not rare in the blue waters of Puerto Rico.

3. *Carcharhinus obscurus* (LeSueur)

The dusky ground shark is characterized by a mid-dorsal ridge on the back between the dorsal fins; the first dorsal fin is less in vertical height than the distance from the eye to the first gill opening. This shark is commonly caught trolling by fishermen at La Parguera. Specimens observed to date have varied from about 10 to 190 lbs.

4. *Aprionodon isodon* (Muller and Henle)

The record is based on a small 2 foot specimen, UPR-899, collected by Ventura Barnés, Jr., in 1942 from the west coast. This shark has small, slender, symmetrical, smooth edged teeth in both jaws.

5. *Scoliodon terranovae* (Richardson)

This small species is abundant around Puerto Rico. It has well marked labial furrows at the corners of the mouth, and is frequently caught in beach seines along the west coast.

6. *Negaprion brevirostris* (Poey)

The lemon shark is characterized by the dorsal fins being nearly equal in length, and the snout broadly rounded. Specimens have been seen at La Parguera and Desecheo. Two individuals lived for over a year at the Marine Laboratory at La Parguera.

Family SQUALIDAE. Spiny dogfishes

7. *Squalis cubensis* (Howell Rivero)

A specimen was collected in 1951 at Aguadilla, but has since been lost. There is a single long spine in front of each dorsal fin.

Family MUSTELIDAE. Smooth dogfishes

8. *Mustelus canis* (Mitchill)

The smooth dogfish may be distinguished from the other sharks reported here by having spiracles behind the eyes, and paved teeth in the jaws. Two specimens are in the collection, obtained from western Puerto Rico in 1951.

Family ISURIDAE. Mackerel sharks

9. *Isurus oxyrhinchus* (Rafinesque)

A mako shark was caught by rod and reel off San Juan in January 1955; it weighed 192 lbs. A photograph is in the newspaper "El Mundo" for Jan. 21, 1955. The almost equal size of each lobe of the tail and the smooth edged recurved narrow teeth are characteristic of this species. In Dec. 1955, a commercial fisherman caught a 400

lb. mako or "tiburon carite" off Desecheo Island. The teeth and jaws of this shark are now in the College collection.

Family Xenocongridae. Eels

10. *Kaupichthys atlanticus* Böhlke

Two small eels collected from Puerto Rico belong to this species. The specimens are now at the Chicago Natural History Museum.

Family Echelidae. Worm eels

11. *Myrophis egmontis* Jordan

One small eel, catalogue No. UPR-802, was collected by the author with rotenone from coral rocks near shore east of Guanica in June 1954. The dorsal fin begins behind the vent.

Family Moringuidae

12. *Stilbiscus edwardsi* Jordan and Bollman

This record is based on one specimen collected from a shallow shore reef with rotenone at Punta Arenas in summer of 1951. The specimen is now at the Chicago Natural History Museum.

Family Muraenidae. The moray eels

13. *Enchelycore nigricans* (Bonnaterre)

Three eels, the largest 23″ T. L., from Playa Jaboncillo, Guanica are catalogued as UPR-960. The lips do not meet when the jaws are closed; this character distinguishes this genus readily from *Gymnothorax*. The light brown with dark brown spotting in the two smaller specimens is replaced by uniform black in the largest specimen.

14. *Gymnothorax vicinus* (Castlenau)

This moray is common over grassy bottom at La Parguera. It is sometimes confused with *G. moringa* or *G. funebris*. It is mottled light brown on an almost yellow background.

15. *Gymnothorax obscuratus* (Poey)

One specimen was caught and preserved at La Parguera in 1954. The purple blotches with bright yellow background give a distinctive color pattern to this species.

16. *Channomuraena vittata* (Richardson)

A two foot specimen of this finless moray was caught in a fish pot off La Parguera on Nov. 13, 1954. It was unknown to all the local fishermen and is a new record from Puerto Rico. The specimen has been preserved.

Family Belonidae. The needlefishes

17. *Ablennes hians* (Cuvier and Valenciennes)

This flat-sided needlefish is reported from a specimen collected by the author at Aguadilla, Dec. 7, 1954. It was caught in a beach seine at Playhuela, and is locally called "tijerilla".

Family Hemiramphidae. The halfbeaks or "balajus"

18. *Euleptorhamphus velox* Poey

The flying halfbeak is reported on the basis of a specimen collected from the stomach of a dolphin *Coryphaena hippurus* at La Parguera on May 1, 1955. The fish had well developed eggs. Fishes that act like flying halfbeaks have been reported by charter boat captains at San Juan.

Family Exocoetidae. The flying fishes

19. *Cypselurus heterurus* (Rafinesque)

This species is probably the largest occurring in Puerto Rican waters. and is more common during the winter months. It is frequently found in the stomachs of dolphins *Coryphaena hippurus*. One specimen, 11″ T. L., with developed eggs, was collected from a dolphin stomach at La Parguera on April 1, 1956, and was preserved.

20. *Cypselurus comatus* (Mitchill)

A specimen 7½″ T. L. was given to the author at San Juan in May 1955 and appears to be this species.

21. *Cypselurus furcatus* (Mitchill)

This flying fish has been collected with rotenone at Desecheo in July 1952. One was also seen under a night light at La Parguera in Sept. 1954, and was probably this species.

22. *Halocypselus evolans* (Linnaeus)

Two flyingfishes flew aboard the author's sloop when crossing the Vieques passage on the night of Dec. 24, 1955. They were both about 8 inches in total length.

23. *Exonautes rufipinnis* (Cuvier and Valenciennes)

A small 5 inch flyingfish from the Mona Passage taken in July 1955 is in the College collection, and seems referrable to this species.

Family Holocentridae. The squirrel fishes

24. *Holocentrus coruscus* (Poey)

This squirrel fish is common around Puerto Rico, though it does not occur in the commercial catch. It is frequently caught with rote-

none when collecting for scientific purposes. The pronounced black color on the first dorsal fin helps identify this species in the field.

25. *Plectrypops retrospinis* (Guichenot)

A specimen 3¼″ T. L., UPR-160, was collected by Luis Rivas and his students at Caña Gorda, beach, Guanica on Aug. 3, 1951. This is the only specimen colleced to date.

26. *Osteichthys trachypomus* (Gunther)

This small squirrel fish is apparently rare. The author and students collected two specimens with rotenone at the eastern end of Magueyes Island, La Parguera, on Feb. 17, 1954, UPR-161. Another specimen, UPR-162, was collected by Cable and LeZotte from Cabo Rojo. The author collected a fourth specimen from the stomach of a dolphin *Coryphaena* on March 5, 1955. One specimen is at the Chicago Museum.

Family Polymixiidae. The barbudos

27. *Polymixia lowei* Gunther

One specimen, UPR-571, was caught bottom fishing at Pt. Higuero on July 21, 1951. Another was taken by a fisherman at La Parguera on March 22, 1955.

Family Scombridae. Mackerels and tunas

28. *Euthynnus alletteratus* (Rafinesque)

The false albacore is probably the most abundant scombrid in Puerto Rican waters, but to date it has not been recorded in scientific literature on the island fish fauna. It is called "albacora" at La Parguera, "vaca" at Mayagüez and Aguadilla, and "bonito" at San Juan. One fish, UPR-897, is in the collection. During June and July, they are sometimes caught in great numbers by beach seines from Rincón to Aguadilla. The name "vaca" meaning cow is said to refer to the fact of the frequent passing of milt by the males during this season; the milt being white in color resembles milk.

29. *Katsuwonus pelamis* (Linnaeus)

The oceanic or arctic bonito grows to a large size in Puerto Rican waters. Bonitos over 30 lbs. have been caught by sport fishermen off San Juan. One man reported seeing a 45 pounder in the fish market at Aguadilla.

30. *Thunnus obesus* (Lowe)

The big eye tuna has recently been reported from the Caribbean by Bullis and Mather (1956). Mr. Rolf Juhl reported a specimen

which was caught by long line south of Ponce in the summer of 1955. The fish weighed 180 lbs. and had 19 + 6 gill rakers on the first gill arch.

31. *Thunnus atlanticus* (Lesson)

The blackfin tuna is the most abundant species of *Thunnus* in the waters of Puerto Rico. It is called "albacora" at San Juan, "bonito" at Aguadilla, and "atún" at La Parguera. The sportfishing record for the species is 22 lbs. in Puerto Rico. It is abundant most of the year at Aguadilla, the average weight being around 6 lbs.

32. *Thunnus albacares* (Bonnaterre)

The yellowfin or Allison tuna is the large common tuna of Puerto Rican waters. It attains a weight of over 200 lbs., though the sportfishing record is only 168 lbs. It is apparently most abundant in early summer.

33. *Thunnus thynnus* (Linnaeus)

The bluefin tuna was first recorded from Puerto Rico on Sept. 10, 1955 with a 162 lb. specimen caught by rod and reel off San Juan. This very interesting record is supported by a good photograph published in "El Mundo" on Sept. 17, 1955. Reports of very large tuna are made from time to time which would indicate that there may be more bluefin tunas around Puerto Rico.

34. *Thunnus alalunga* (Gmelin)

The true albacore has been caught recently by long line in waters around Puerto Rico. The average size of these tunas is around 60 lbs. Sportfishermen have told the author that in former years, the albacore was caught closer to shore.

35. *Acanthocybium solandri* (Cuvier and Valenciennes)

The wahoo or peto is fairly common. Good catches have been made off Grappler's bank, some 15 miles southeast of Guayama, in November and December.

Family GEMPYLIDAE. The snake mackerels

36. *Gempylus serpens* (Cuvier and Valenciennes)

The snake mackerel is probably more common around Puerto Rico than collections would indicate. A specimen from the Mona Passage, UPR-176, is in the College collection. On April 15, 1955, the author caught a specimen 18″ T. L. off Guayanilla; this fish is now preserved at Woods Hole.

Family CARANGIDAE. The jacks and runners

37. *Decapterus macarellus* (Cuvier and Valenciennes)

This small robin or scad is called "caballa" at Aguadilla. A specimen was collected at Aguadilla on March 12, 1956, at which time this species was more abundant than *D. punctatus* which has already been recorded from Puerto Rico. *D. macarellus* has about 25 scutes on the caudal peduncle; its blue color and slimmer body distinguish it readily in life from *D. punctatus* which has a pronounced yellow lengthwise stripe and larger but more numerous scutes about 35 in number.

38. *Seriola dumerili* (Risso)

This amberjack grows up to 100 lbs. or more. It is more elongate and less deep in body than *S. falcatus* and does not have elongate dorsal and anal fins. The local name is "medregal".

39. *Elegatis bipinnulatus* (Quoy and Gaimard)

The rainbow runner or "salmón" is occasionally caught trolling around the Island. Some fishermen say that this fish tends to travel with sharks. A specimen is in the College collection. The single detached finlet behind the dorsal and anal fin is distinctive.

40. *Alectis crinitus* (Mitchill)

The African pompano occasionally occurs in the commercial fishery. It is usually caught by trolling. It is called "sol" at La Parguera and "corcobado de pluma" at Fajardo. Two 18 pounders were caught by a La Paraguera fisherman in July 1955. Both fishes had long filaments extending from the soft dorsal and anal fins.

41. *Caranx lugubris* (Poey)

This square headed black jack is called "jurel negron" in Puerto Rico. It is often caught by trolling near offshore islands such as Mona and Desecheo.

42. *Caranx guara* (Bonnaterre)

This record is based on a mutilated specimen, UPR-896, collected by Barnes in 1942, presumably from the Mona passage. The oval-shape of this species and the long gradual decurving arch of the lateral line are distinctive. The gills are missing.

43. *Trachinotus falcatus* (Linnaeus)

The permit or "Pampano" grows up to 35 lbs. or more in Puerto Rican waters. Good catches of permits have been made by sport-fishermen at Aguadilla.

Family CORYPHAENIDAE. The dolphins

44. *Coryphaena equisetis* (Linnaeus) Small dolphin

On August 28, 1956, numerous small dolphins from 12 to 14

inches in tail fork length were caught by sportfishermen off San Juan. The gonads were well developed with well formed eggs in the ovaries. The tail fork length was 3 to 3½ times the greatest body depth. Two preserved specimens were compared with two young specimens of *C. hippurus* of the same size collected from La Parguera in July 1956. The tail fork length of *C. hippurus* was over 4 times the greatest body depth.

45. *Coryphaena hippurus* Linnaeus

The dolphin or "dorado" is abundant especially in February and March. The insular record for sportfishermen is 59 lbs. and 4 oz.; dolphin around 50 lbs. are not rare. During the summer from June through September, few dolphins are caught; the few that are caught during the summer are often small, from one to two pounds in weight. The distribution by month of reported catches of 562 dolphins from 1951 through March 1956 gives a fairly accurate idea of relative seasonal abundance of dolphins in Puerto Rican waters:

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	Total
91	199	91	41	43	4	3	-	4	47	23	16	562 dolphins

Ovaries with eggs in the most advanced stage of development have been found in February.

Family Nomeidae. Man-o'war fishes

46. *Psenes cyanophrys* Cuvier and Valenciennes

The author collected a 3″ fish with golden sheen and fine black dotting on its sides from the stomach of an 18 lb. *Coryphaena* on Mar. 24, 1956 at La Parguera. Since that date, several more have been collected in the same manner.

Family Bramidae. "Sea breams"

47. *Brama raii* (Bloch)

A specimen about 10″ long, now at the U. S. National Museum, was collected by Barnés in 1942. On March 28, 1955, the author collected a 3″ specimen in almost perfect condition from the stomach of a dolphin at La Parguera.

Family Xiphiidae. The swordfishes

48. *Xiphias gladius* (Linnaeus)

A small swordfish was reported caught by long line fishing off the south coast in 1955. On March 15, 1956, the author found the remains of a small swordfish about 21″ long in the stomach of a 20 lb. *Coryphaena hippurus* at La Parguera. The flat sword measured 6½″

and the under jaw 3″, both of which have been preserved. The head was completely destroyed and the body and tail were unfortunately washed overboard. On March 29, 1956 the author found in the stomach of a 96 lb. blue marlin at La Parguera another small swordfish which measured about 9¼″ T.L. with the upper jaw 2½″ long and the lower jaw about 2⅛″. Scales on the back and below have 4 to 5 visible spines.

Family ISTIOPHORIDAE. "The billfishes"

49. *Istiophorus americanus* (Cuvier and Valenciennes)

Sailfish are caught occasionally by sportfishermen around the island, where they are most abundant from October to April. There are no catch records from June or July from Puerto Rico and only one sight record from La Parguera in July 1955. The largest fish recorded from the island is 68½ lbs. and the smallest about 10 lbs.

50. *Makaira ampla* (Poey) blue marlin

The blue marlin is caught throughout the year in Puerto Rico. It is apparently more abundant than either the sailfish or the white marlin. The blue marlin seems to be somewhat scarce in July and more abundant in September and October. The marlin running in October are a smaller average size than the marlin in September. A marlin 286 lbs., caught off Mayagüez in September 1955, had developed ovaries weighing a total of 4¼ lbs.; the eggs inside the ovaries were well formed. The Atlantic record of 756 lbs. is now held by Puerto Rico; the fish was caught in April 1956. The smallest blue marlin recorded from Puerto Rico is 46 lbs. caught off San Juan in Dec. 1956.

51. *Makaira albida* (Poey) white marlin

The white marlin appears to be scarce in Puerto Rican waters in August for which there are no catch records and September for which there are only two records. April seems to be the peak month for this species, and enlarged ovaries have been reported during the month. Mr. Víctor Rivera, charter boat captain at San Juan, saved eggs from a 61 lb. white marlin caught on June 9, 1956; these are the most well formed and developed eggs yet seen by the author for this species. The largest record was a 91 lb. fish caught in April 1955, and the smallest is around 22 lbs.

Family APOGONIDAE. The cardinal fishes

52. *Apogon binotatus* (Poey)

There are 3 specimens, UPR-216, in the collection obtained by Rivas and students at Punta Arenas in the summer of 1951.

Family Centropomidae. Snooks or robalos

53. *Centropomus ensiferus* (Poey)

This species is apparently the more abundant snook in Puerto Rico. The low scale count (about 50-55) above the lateral line is distinctive. It is said by fishermen not to exceed about 2 lbs. in weight; in life the anal fin is bright yellow. The large snook of Puerto Rico is *C. undecimalis,* for which the rod and reel record is 34 lbs. Both *C. pectinatus* and *C. parallelus* which have been recorded in the literature from Puerto Rico have not yet been seen by the author. Most of the numerous specimens in the collection at Mayagüez are this species and a few are *C. undecimalis.*

Family Serranidae. The sea basses and groupers

54. *Epinephelus mystacinus* (Poey)

This fish is called "guasa" in Puerto Rico. The large head and eyes together with the posterior nostril opening being considerably larger than the anterior help to distinguish this species. When it is brought up from the bottom, pressure invariably forces the eyes out of the sockets. It is occasionally caught bottom fishing in deeper water by commercial fishermen.

55. *Promicrops itaiara* (Lichtenstein)

The spotted jewfish is called "mero sapo", "mero batata", or "mero grande" in Puerto Rico. The large size, profuse black spotting over the head and body, and the wide space between the eyes are characteristic of this species. A jewfish of 187 lbs. speared near Ramey Field had three fair sized spiny lobsters, *Panulirus argus,* in its stomach. This species, while not abundant, occurs with regularity around the island.

56. *Mycteroperca interstitialis* (Poey)

This grouper is more often referred to as *M. falcatus* in the literature, but the other name has page precedence. Two specimens, UPR-825, collected by J. A. Ramos from Puerto Real (Cabo Rojo) market in October 1951 are apparently this species. The color is uniform dark brown without any spotting.

57. *Mycteroperca venenosa* (Linnaeus)

The yellowfin grouper was reported as a new species, *M. bowersi*

(Evermann and Marsh). This name was synonomized with *M. venenosa* by Longley and Hildebrand in 1941. It is not rare and is occasionally caught by spearfishermen, or by slow trolling over rock bottom.

58. *Dermatolepis inermis* (Cuvier and Valenciennes)

This deep bodied grouper is called "boricua" at Salinas. It is characteristically black or dark brown with whitish or light colored blotches over the body. A good specimen, UPR-824, from La Parguera has been preserved. It apparently is not common.

59. *Prionodes tigrinus* (Bloch)

There is only one specimen, 4¼″ T. L., UPR-259, in the collection from Boqueron by Arturo Dávila around 1940. The curiously black mottled pattern on a white background is very distinctive.

60. *Prionodes phoebe* (Poey)

A specimen, UPR-258, 6″ in T L. was caught by a commercial fisherman by hook and line in deep water off Rincón on August 3, 1951.

61. *Prionodes tabacaria* (Cuvier and Valenciennes)

Several specimens have been seen and collected by the author from La Parguera in 1954 and 1955. They are occasionally caught by commercial fishermen when bottom fishing for snappers. The brilliant rich orange color in life of this species is striking.

Family PEMPHERIDAE. The deep water catalufas

62. *Pempheris mulleri* Poey

C. L. Smith, Jr. skillfully speared a specimen of this species near shore at San Juan in July 1955. About 25 specimens were collected with rotenone by Biaggi and students from Cabo Rojo Lighthouse in April, 1946.

Family LUTJANIDAE. The snappers

63. *Lutjanus buccanella* (Cuvier and Valenciennes)

The blackfin snapper or "negra" is commonly caught bottom fishing in deeper water off Puerto Rico. The black spot at the base of the pectoral fin and the bright red body color are characteristic.

64. *Pristopomoides macrophthalmus* (Müller and Troschel)

This large eyed snapper is called "muniama" at La Parguera by fishermen who catch them fairly regularly bottom fishing. The large eye, scaleless fins, and silver pink color help to distinguish it.

Family Haemulidae. The grunts

65. *Brachygenys chrysargyreus* (Gunter)

This little grunt with straight horizontal lines of deep yellow color on a silver background occurs occassionally in fish pot catches from La Parguera, El Combate, Puerto Real de Cabo Rojo, etc. "Cici" or "saboga" are local names in use, but it is not very familiar to most fishermen.

Family Sciaenidae. *The croakers*

66. *Stellifer stellifer* (Block)

This little croaker or "curbina" is common on muddy bottoms in Añasco and Mayagüez Bays. It is most common fish picked up by the use of shrimp trawls. The small eyes and almost transparent cavernous skull are distinctive. The fishes average 2 to 3 inches in length. Some specimens, UPR-462, 463, are in the College collection.

Family Pomacentridae. The demoiselles

67. *Chromis marginatus* (Castlenau)

This species is common in shallow waters behind reefs at La Parguera. They are occasionally caught in fish pots. The body color in life is greyish with some silver below. The dorsal and caudal fins are edged with black. The gonads are ripe in May.

68. *Chromis cyanea* (Poey)

This species is reported on the basis of sight records by the author off Desecheo Island in July 1952. They are small 2 to 3″ with a brilliant blue color when they are swimming in the water, and the forked tail is evident.

Family Labridae. The wrasses

69. *Halichoeres maculipinna* (Müller and Troschel)

A specimen, 3¾″ T. L., UPR-528, was collected with rotenone from Playa Tamarindo, Guanica. It is apparently one of the less common wrasses in Puerto Rico.

70. *Halichoeres bivittata* (Bloch)

Though not a new record, this species is mentioned because of the striking color difference between large males of about 1 foot in length and smaller fishes: the large males formerly referred to as *H. cyanocephalus* have green heads with blue black sides and are apparently only caught in deeper water by fish pots. The smaller fishes are very common over grass bottom in shallow water and characteristically have

a pattern of two black stripes along the back with reddish orange color on the fins.

Family SCARIDAE. The parrotfishes

71. *Scarus acutus* (Poey)

Apparently less common than the other parrotfishes, it is seen from time to time in the commercial fish catches at La Parguera. In April 1954, the author saw them in moderate abundance in shallow water at the north end of Sardinera Anchorage, Mona Island. The broad longitudinal brown and white stripes help to distinguish this species. A specimen in the College collection has lateral canine teeth and is about one foot in length. Smaller fishes lack the lateral canines.

72. *Psuedoscarus coelestinus* (Cuvier and Valenciennes)

This dark blue-black parrotfish with pale blue borders on its fins and irregular pale blue marks on the side of the head has blue green teeth. It is taken with some regularity from fish pots at La Parguera but is far less abundant than *P. guacamaia.*

73. *Sparisoma radians*

On Nov. 5, 1956, the writer found a parrotfish at La Parguera with ripe eggs. The eggs were perfectly round and transparent and were about ½ mm in diameter. Each egg had a tiny yellow oil globule. The fish measured 6.5 mm T. L. and was caught in a fish pot.

Family CHAETODONTIDAE. Butterfly and angelfishes

74. *Chaetodon sedentarius* (Poey)

The black peduncle band extending on to the dorsal and anal fins is supposedly characteristic. It is not very common, but there are three specimens, UPR-576, 579, in the College collection.

75. *Pomacanthus arcuatus* (Linnaeus)

With some hestitation, the author follows Longley and Hildebrand 1941 in the change of name *P. paru* to *P. arcuatus.* The French angelfish is dark black in color with bright yellow edges to the scales on the sides; the lines on the head are yellow. It occurs with regularity around the island but is somewhat less abundant than the black angelfish *P. aureus* (formerly referred to as *P. arcuatus). P. aureus* has white markings on the head and is rather brownish in color with dark centers on the scales.

Family BALISTIDAE. The triggerfishes

76. *Balistes capriscus* (Gmelin)

The common triggerfish is rare in Puerto Rican waters, but several

have been seen at La Parguera. It differs from *B. vetula* in the less brilliant blues and yellows; it also has a distinctive dark area in the region of the pectoral fin which color is only evident in life.

77. *Canthidermis sobaco* (Poey)

An ocean triggerfish over one foot in length was caught in a fish pot off La Parguera on Feb. 11, 1956, and was preserved by the author.

78. *Xanichthys ringens* (Linnaeus)

This species is reported because specimens were found in great abundance in the stomachs of blue marlins and dolphins caught during a fishing tournament at San Juan in October 1954.

Family Monacanthidae. The filefishes

79. *Alutera schoepfi* (Walbaum)

A filefish which was light tan in color and had the eye situated low in the head (about the middle of the head) lived in an open cage for over a year at the Marine Laboratory pier at Magueyes Island, La Parguera. It was over a foot long when last seen and has probably since died. Though the color was somewhat different than the author has seen in orange filefishes from Orient, N. Y., the fish was probably this species mainly because of the central location of the eye in the head.

80. *Alutera punctata* (Agassiz)

The spotted filefish or "pereza" is apparently more abundant than *A. scripta* in Puerto Rican waters. Small black young of 2″ and up which the author has found proved to be *A. punctata* because of the lower dorsal and anal ray counts. Adult *A. scripta,* however, are encountered just as commonly as *A. punctata.*

Family Gobiidae. The gobies

81. *Erotelis smaragdus* (Cuvier and Valenciennes)

The author collected several of these small elongate gobies with rotenone from mud bottom under red mangroves east of Pt. Monserrate, Luquillo Beach on Sept. 15, 1948. The specimens are now at the U. S. National Museum.

82. *Lophogobius cyprinoides* (Pallas)

This crested goby is found occasionally in red mangrove inlets. Specimens have been collected from Luquillo Beach and La Parguera and Caño Corazones near Mayagüez. Younger gobies one to two inches have a bright yellow spot on the head crest which becomes

uniform black in older fishes.

83. *Gobius ebriosus*

This little light red goby is hardly one inch in length; in shape of head and body it resembles *Bathygobius*. The author has collected them with rotenone from Luquillo Beach reefs and from a rock splash pool just east of the mouth of the Guajataca River. The specimen from Luquillo was identified by Isaac Ginsburg at the U. S. National Museum. At the College are 6 specimens, UPR-848, from Guajataca.

84. *Gobiosoma novemlineatum* (Fowler)

This tiny goby with bright red eyes and nine thin pale blue bands on a dark brown body lives in association with sea urchins, *Echinometra*, in their rock holes. Specimens of this species were first collected by the author and students with rotenone on June 14, 1954 from the rock splash pool near the mouth of the Guajataca River; 17 specimens are catalogued as UPR-851 (4 specimens, now at the U. S. National Museum were identified by Ginsburg). C. L. Smith, Jr. and the author collected additional specimens at Condado rocks.

85. *Gobiosoma oceanops* (Jordan)

This black and white goby has an affinity for stony corals, especially the brown coral, *Monastrea annularis*. The author has observed them at Port Antonio, Jamaica, Port-au-Prince, Haití, and La Parguera, Puerto Rico. They live in holes in the stony corals and are frequently seen swimming along the water surface. On May 26, 1956, 4 gobies were collected with rotenone from a coral head in about three feet of water at Ogado reef, La Parguera.

86. *Gobiosoma horsti* Metzelaar

C. L. Smith, Jr. collected 3 of these gobies from Condado rocks. He has kindly compared two of the specimens of *oceanops* with his and has informed the author by letter of the differences he has found. The best character difference is the presence of a premaxillary frenum in *G. oceanops* which is lacking in *G. horsti*. It may be that these two similar species have different ecological preferences. Condado rocks is largely a beach rock formation affected by considerable wave surge. Ogado reef on the other hand is an inner reef at La Parguera with living stony corals in considerable abundance. Sea urchins, *Echinometra*, are abundant on Condado Rocks but relatively few at Ogado, where the long spined *Diadema* abounds.

87. *Gobionellus claytoni* (Meek)

One specimen collected by the author in Nov. 1945 from near the

mouth of Río Grande de Loíza was identified by Ginsburg as this species. The specimen is now at the U. S. National Museum.

88. *Gnatholepis thompsoni* (Jordan)

A specimen was collected by the author at Punta San Diego, Fajardo, in Nov. 1945. It was caught on sand bottom in a small rock pool. The fish is at the National Museum.

89. *Rhinogobius mowbrayi* (Bean)

This small goby with dark brown bands on a light background has been collected by the author at Ogado reef, La Parguera, and by Smith at Condado Rocks.

90. *Barbulifer cauthoecus* (Jordan and Gilbert)

This small species with a bearded white head and a black body is one that is not easily confused with others. The author has collected them from beach rocks east of Guanica and at Guajataca, UPR-850, 947.

Family Rachycentridae. The cobias

91. *Rachycentron canadus* (Linnaeus)

The cobia or "bacalao" (as it is called in Puerto Rico) is occasionally caught during the summer months. It has been reported locally in association with sharks. Several specimens have been seen from Guanica and La Parguera.

Family Echeneidae. The shark suckers

92. *Remora remora* (Linnaeus)

One offshore shark remora with 18 laminae on the head and a short tail was collected by Barnés on Oct. 17, 1942 from a dusky shark caught at Sponge Bank, northwest of Mayagüez.

93. *Rhombochirus osteochir* (Cuvier)

The spearfish remora has been collected on a number of occasions from blue marlins in Puerto Rico. One remora collected in May 1955 had clear ripe eggs. The adults are a dull grey in color, almost black, and average around 8 inches in length. Young remoras of this same species of around two inches in length are blue on the back and silver on the belly.

Family Opisthognathidae. The jawfishes

94. *Opositho gnathus maxillosus* (Poey)

The jawfishes live in neatly made holes in hard sand among patches of coral. Specimens have been collected from Maunabo (2 specimens

at the National Museum) and Guanica, UPR-699, 941. Smith has collected them at Condado Rocks.

Family Gobiesocidae. The clingfishes

95. *Gobiesox nigripinnis* (Peters)

A clingfish collected by Dr. R. M. Cable at Mona Island in November 1951 and one by the author from Salinas Bay, Cabo Rojo, UPR-930, appear to be this species.

96. *Arcos macropthalmus* (Gunther)

A large specimen 3¼″ T. L. was collected on March 18, 1945 from a rock washed by surf at Punta San Diego, Fajardo. The clingfish was dull yellow color in life and turned quickly to bright pink when placed in formalin. The specimen is now at the U. S. National Museum. Though not a new species record *(Gobiesox cerasinus* Cope being a synonym), the large size of this specimen is noteworthy.

97. *Gobiesox strumosus* (Cope)

Many specimens of this species were collected with rotenone from under a rock at Desecheo Island, UPR-696. At the same time numerous *Arcos* were collected.

98. *Acyrtops beryllinus* (Hildebrand and Ginsburg)

Several small clingfishes were collected from rocks near Cabo Rojo Lighthouse by Elinor H. Behre in Dec. 1945. The specimens are now at the National Museum.

99. *Tomicodon fasciatus* (Peters)

Several clingfishes collected from Punta San Diego, Fajardo and San Juan are now at the American Museum of Natural History and were identified by J. T. Nichols. Some specimens from Guanica, UPR-948, are probably this species. They are sometimes found in beach rock crevices when the tide is falling, but are most apt to be found in water rivulets trickling back quickly into the sea after a receding wave.

Family Brotulidae.

100. *Brotula barbata* (Bloch and Schneider)

A specimen, 23″ T. L., was collected by Barnés from deep water off the west coast around 1942. This fish is in the College collection.

101. *Dinematichthys cayorum* (Evermann and Kendall)

A female with eyed young inside its abdomen was collected by the author and students with rotenone from a shore reef east of Guanica in June 1954. These little bright yellow or orange fishes are abundant

in coral reef areas near shore. There are several in the collection.

Family Ophidiidae

102. *Lepophidium profundorum* (Gill)

This species has a downward pointing spine at the tip of its snout. Barnés collected several specimens from deep water. One is UPR-709, and at least two others from Puerto Rico are at the National Museum.

Family Ogcocephalidae. The batfishes

103. *Ogcocephalus parvus* Longley and Hildebrand

On Jan. 12, 1956, a batfish about 3″ long with bright red lips and a short nose was collected from a fisherman at Joyuda. It was caught in a fish pot in about 30 fathoms, and has 12 pectoral rays. It is now at the National Museum and has been compared with the type by Dr. Schultz.

Addendum

Family Xenocongridae

104. *Ariosoma impressa* (Poey)

A large eyed eel of 6 inches in length was collected by Dr. M. J. Allen under a night light at Magueyes Island, La Parguera, on Dec. 25, 1955. The specimen is now at the U. S. National Museum and was identified by Mr. Robert H. Kanazawa.

Family Heterenchelidae

105. *Heterenchelys biaggii* Böhlke

This elongate eel is characterized by a short body and long tail. Three specimens were collected by Dr. Biaggi from a dredge in Mayagüez harbor in April 1934. They are apparently dwellers in soft black mud bottom.

Family Ophichthidae. The snake eels

106. *Aplatophis chauliodus* Böhlke

A strange eel with long irregular teeth was collected by Dr. Biaggi from a dredge in Mayagüez harbor in April 1934. Some twenty years later, Dr. Biaggi found another smaller specimen in Caño Corazones, a muddy bottom inlet surrounded by mangroves and located south of Mayagüez. He always has referred to this eel as the "toothy eel" which is an excellent name.

Family Chiasmodontidae. Black swallowers

107. *Pseudoscopelus scriptus* Lütken

A deep sea fish in poor condition was found in the stomach of a 96 lb. blue marlin on March 26, 1956 at La Parguera. In the stomach of the *Pseudoscopelus,* however, were found three copper colored larval fishes and one deep bodied fish with a very protractile maxillary in almost perfect condition. Mr. Kanazawa at the National Museum identified the deep sea fish as *Pseudoscopelus,* the copper colored fish as *Holacanthus,* and the protractile mouthed fish as a tholichthys stage of a chaetodont. Perhaps the protractile mouthed fish is the young of *Prognathodes aculeatus* if it is not the young of *Capros aper;* see figure on page 228 of Goode and Bean, 1895 "Oceanic Ichthyology," which figure this fish closely resembles.

Family Brotulidae

108. *Petrotyx sanguineus* (Meek and Hildebrand)

On Feb. 18, 1956, the author collected, in company with Dr. Biaggi and students, a two inch crimson red brotulid with rotenone from a shore reef at Punta Arenas, south of Mayagüez. The specimen is in the College collection and compares well with the figure in Böhlke, 1955, Notulae Nature, No. 273. *Dinematichthys* were collected in great numbers from the same area.

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A PRENAUPLIOSOMA STAGE IN THE LARVAL DEVELOPMENT OF THE SPINY LOBSTER, *PANULIRUS ARGUS* (LATREILLE), FROM PUERTO RICO[1]

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ABSTRACT

A prenaupliosoma stage is described for *Panulirus argus* (Latreille), which is similar to that described by Von Bonde (1936) for *Jasus lalandii* (Milne Edwards). Further investigation will be needed to establish whether this stage occurs only within the egg, but the possibility exists that it might be released by the action of the fifth dactyl of the female, while tending the eggs.

INTRODUCTION

The actual and potential value of the spiny lobster, *Panulirus argus* (Latreille), to both the commercial and sport fisheries of Puerto Rico is considerable. The Section of Fishery and Wildlife of the Department of Agriculture of P.R. initiated in 1955 a biological study of this species in order to ensure a successful management of the fishery. The present work forms part of that investigation.

The author wishes to express his sincere thanks to the staff of the Marine Laboratory of the University of Miami for the facilities furnished, and especially to Dr. Gilbert L. Voss and Dr. Clarence P. Idyll for their guidance. I am particularly indebted to Mr. Felix Iñigo and Mr. Donald S. Erdman, Chief and Fishery Biologist respectively of the Fish and Wildlife Section of P.R., who generously furnished their experience and assistance.

MATERIALS AND METHODS

There is a change in the coloration of the lobster egg as the embryo develops and the yolk material is absorbed. The recently laid egg is of a bright orange-red color, then it turns dark brown, light brown, and finally attains a whitish or colorless appearance when it is ready to hatch. In order to study the egg content throughout this range of coloration, sample of eggs were collected in November,

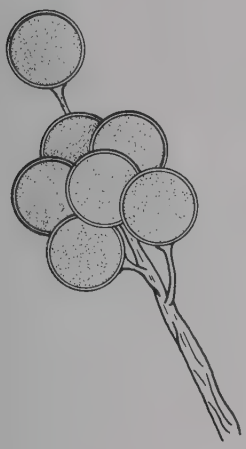
[1]Contribution No. 171 from The Marine Laboratory, University of Miami.

1956, from the commercial landings of the fishery at Culebra Island, Puerto Rico. They were preserved in 7% formalin, examined microscopically and their diameter measured with a micrometer eyepiece. Ridway's color chart (1912) was used for the determination of the various colors. The illustrations are by the author, except Figure 1e, which is from the pen of Mr. Thomas McKenney, assistant at the Marine Laboratory of the University of Miami.

Discussion

The eggs were more or less spherical, having a diameter of about 0.7 mm. The structure and attachment was similar to that described by Von Bonde (1936) for *Jasus lalandii* (Milne Edwards). The space between the egg content and the chitin capsule was larger in the younger eggs, and was gradually filled by the developing embryo, the diameter of the egg remaining more or less constant in the different samples. The following color sequence in the development of the eggs was found: (1) orange chrome with homogeneous yolk content, (Fig. 1a); (2) salmon orange with the eyes beginning to differentiate, (Fig. 1b); (3) amber brown with the embryo almost developed, showing the appendages compactly folded around the body and exhibiting a red pigmentation in them, (Fig. 1c); (4) Sanford's brown showing further differentiation with many of the embryos in a prenaupliosoma stage (Fig. 1d-e) similar to that described by Von Bonde (op. cit.). Many of the embryos in this stage were found outside of the ruptured eggs. Most of these embryos still retained the shape they had within the egg, that is, the body was bent on itself with the appendages closely folded up around it, passing from the ventral side, through between the eyes, to some distance over the cephalic region; but some were found with the body and the appendages completely distended.

The examination of this stage required great patience and care due to the tendency of the delicate appendages to wrap around the body. There was still some yolk left in the cephalic region but the rest of the body was transparent, with a bubble-like appearance within the appendages and some pigmentation at the end of the legs. Its general description corresponds closely to that given by Von Bonde, but the biramous antennae were found to be devoid of any setae and a ridge was observed along the median line of the carapace. The cephalic region measured about 0.65 mm; the thoracic region, 0.52 mm; and the abdominal region, 0.28 mm; with an overall



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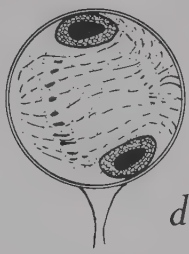

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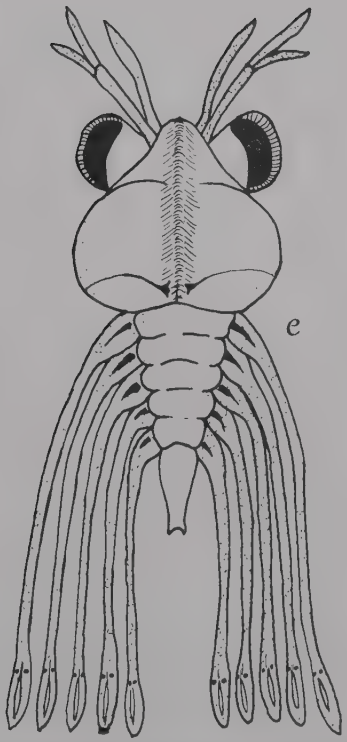

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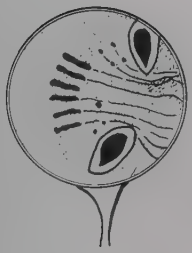

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FIGURE 1. a. Orange chrome eggs with homogeneous yolk content. b. Salmon orange egg with eyes beginning to differentiate. c. Amber brown egg with the embryo nearly developed. d. Sanford's brown egg showing further differentiation of the embryo. e. Prenaupliosoma stage.

length of 1.45 mm, the antennae not included. The cephalic region was 0.63 mm at its broadest section, there was a 0.1 mm separation between the antennules, and 0.73 mm from the outer edge of one eye to the other.

Even though a naupliosoma stage was detected by Sheard (1949) for *Panulirus longipes* (Milne Edwards), neither a prenaupliosoma nor a naupliosoma stage had been recorded in the previous work done on *Panulirus argus*. Both Crawford and DeSmidt (1922) and Lewis (1951) stated that the phyllosoma was the first larval stage for this species, although the former described a condition within the eggs that were ready to hatch which is more or less identical to that found by the author.

Whether both the above stages occur within the egg or hatch as such, as described by Von Bonde (op. cit.), is still to be determined by a careful study of the embryology of this species, since these stages are supposed to last for such a short time that they could pass unnoticed, especially if the eggs hatch at night. There is the possibility, however, that the eggs might be ruptured by the action of the fifth dactyl of the female while it tends the eggs, and that any of these stages could be detected swimming for a while.

Summary

1. The color of the spiny lobster egg changes from a bright orange-red, through different shades of brown, and finally to a whitish or colorless appearance when ready to hatch. The progressive condition of the egg is described as the color pattern changes.

2. A prenaupliosoma stage is described which is similar to that observed by Von Bonde (1936) for *Jasus lalandii,* but differing from this, among other characteristics, by being devoid of setae in the biramous antennae.

3. Further investigation will be needed to establish whether this stage occurs only within the egg, although the possibility exists that the latter might be ruptured by the action of the fifth dactyl of the female while it tends the eggs, thus releasing the larvae.

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REDISCOVERY OF *ANADYOMENE MENZIESII*, A DEEP-WATER GREEN ALGA FROM THE GULF OF MEXICO

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ABSTRACT

Anadyomene menziesii Harvey, a deep-water marine green alga originally collected in the Gulf of Mexico in 1802, was obtained for the second time by the U.S. Fish and Wildlife exploratory vessel OREGON in 1952 in the Gulf and again in 1954. It is considered to be specifically distinct from the shallow water species, *A. stellata* (Wulfen) C. Agardh.

Anadyomene menziesii Harvey is a large green alga of the family Valoniaceae, Order Siphonales. The species is known previously only from the original collection made in 1802 by Archibald Menzies who obtained it by dredging in the Gulf of Mexico in about 20 fathoms of water.

Apparently this rare alga was not collected again for 150 years until it was dredged from a rocky bottom in 45 fathoms (270 feet) by the U.S. Fish and Wildlife exploratory vessel OREGON on June 21, 1952, at 23° 39.8′ N. latitude, 88° 01′ W. longitude. This is OREGON station 592 located about 75 miles north of the center of the Yucatan Peninsula, about 145 miles WNW of Pinar del Rio, Cuba. The bottom is rocky.

A second collection was made from a bottom of white coral mud on April 14, 1954, at OREGON station 1009 at a depth of 200 fathoms at 24° 34′ N. latitude, 83° 34′ W. longitude. The bottom temperature at this station, located about 30 miles west of the Dry Tortugas, was 13°C. at the time of the collection. About two pounds of *A. menziesii* came up in the trawl, part of which was saved. Both these collections were sent to the writer for determination, the first by Stewart Springer, Fishery Engineer in Charge at the time, and the second by Harvey R. Bullis, Jr., Acting Chief of the Gulf Fisheries Exploration and Gear Research at the time the second collection was made.

Mr. Bullis has mentioned, in a private communication, that a considerable quantity of what appeared to be the same species was taken in a trawl in 200 to 225 fathoms south of Mobile, Alabama.

He says, "The ground line of the trawl was completely covered with the stuff, and it certainly looked as if it had just been torn loose from the bottom. It may have come from somewhere up in the

subterranean canyon that extends inshore toward Pensacola. Possibly an unusual type of water run-off occurred that swept the material down the canyon and out onto the slope south of Mobile. This is not a very satisfactory theory, but obtaining green algae at 200 fathoms causes one to speculate. It is puzzling that we have not obtained this species in trawl hauls in shallower water off the Mississippi or Alabama coasts." Specimens of this collection have not been seen by the writer.

Part of the original 1802 collection of *A. menziesii* was sent to W. H. Harvey, an eminent British algologist of the last century, who published a brief description of it (1858) although he did not separate it from *A. stellata* (Wulfen) C. Agardh. Regarding it as a form of *A. stellata,* he says, "The largest specimen measures six inches across and its venation offers some peculiarities; which perhaps may lead to its specific separation . . . Should subsequent observations establish this plant as a species, it may be called *A. menziesii.*" Three other portions of the original collection were deposited in the following herbaria: the British Museum, Kew Gardens, and Menzies' herbarium which was left to the Edinburgh Botanic Gardens. Harvey's herbarium is at Trinity College, Dublin.

In 1866 J. E. Gray renamed the plant *Grayemma menziesii* as he believed that it differed sufficiently from *A. stellata* to justify generic separation; however, his name has not been accepted.

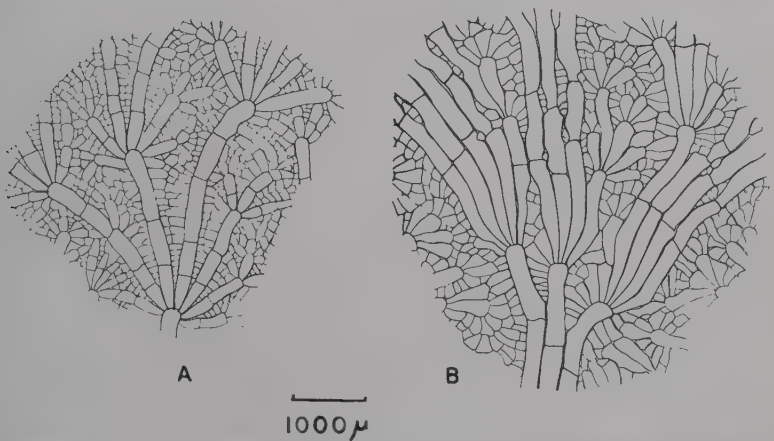

FIGURE 1. A. *Anadyomene stellata.* B. *A. menziesii.* Both as seen in surface view and to the same scale.

A. menziesii forms an expanded, flat, undulate to folded sheet mostly one cell layer in thickness. It is attached to the substratum by a broad disk-shaped holdfast. Throughout the blade are series of fan-shaped, branching, vein-like groups of cells (Fig. 1). All the principal "veins" are composed of 1 to 5 to many parallel, closely-appressed rows of coenocytic cells. The areas between veins are filled with oval to elongate cells with their long axes oriented in different directions.

Specimens from the OREGON collection measure up to 18 inches long and 10 inches in width. Evidently this material was torn by the trawl. Probably large plants reach two to three feet in length and are nearly as wide.

A. stellata differs in having all veins monosiphonous, a maximum size of 2 to 4 inches in height or width, and its range includes waters of somewhat reduced salinity. Reproductive structures have not been reported for either species.

A comparison of collections of the two species shows more striking differences than are conveyed by a description. This has led the writer to doubt that there are intermediate forms between these species and therefore to follow Collin's treatment (1909) and regard them as separate species. *A. menziesii* is obviously restricted to deep water and is probably much more widely distributed than present records indicate. The OREGON collection from 200 fathoms probably represents loose plants which grew in somewhat shallower water as Bullis has suggested, since it seems unlikely that light penetration is sufficient for growth below 100 fathoms, even in the clearest water.

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ASCUS DEVELOPMENT AND SPORE DISCHARGE IN *LEPTOSPHAERIA DISCORS*, A MARINE AND BRACKISH-WATER FUNGUS[1]

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ABSTRACT

Ascus maturation and spore discharge are described for the marine and brackish-water fungus *Leptosphaeria discors*. The mature ascus is bitunicate. Circumscissile rupture of the ectoascus occurs to free the extensile endoascus. A thimble-shaped cap is cast off from the ectoascus and the endoascus elongates through the subsequent fissure. Spore discharge is simultaneous rather than successive, and occurs normally in seawater.

INTRODUCTION

Two principal types of asci are produced by the Pyrenomycetes, a unitunicate (single-walled) and a bitunicate (double-walled) type. The latter is of particular interest because of the nature of the two ascus walls and the various modes of dehiscence of the mature ascus. The importance of ascus morphology is of even greater significance if, as Luttrell (1951, p. 24) points out, variations in ascus structure should ". . . prove to be criteria of fundamental importance in the classification of the Ascomycetes."

Bitunicate asci have been reported for a number of Pyrenomycetes, particularly members of the Mycosphaerellaceae, and for a few Discomycetes. Relatively few Ascomycetes, however, have been studied in detail specifically for ascus morphology and dehiscence. The earliest complete description of the bitunicate ascus is that of Pringsheim (1858) on the aquatic Ascomycete *Pleospora scirpicola*. Brierly (1913) gave a detailed description of the asci and ascospore discharge in *Leptosphaeria lemaneae*. Perhaps the outstanding studies of the bitunicate ascus are those of Hodgetts (1917) on *Leptosphaeria acuata*, and Hoggan (1927) on *Plowrightia ribesia*.

While the general structure of the immature bitunicate ascus seems to be uniform in those species for which it has been reported, variations in the mature ascus have been observed. The majority of these variations, however, have often been considered abnormalities

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resulting from the conditions under which observations were made. In *Leptosphaeria acuata,* for example, Hodgetts observed that the outer ascus wall (ectoascus) split in a circumscissile fashion below the apex, resulting in a thimble-shaped cap which was subsequently cast off from the expanded inner ascus wall (endoascus). This variation, also observed by Butler (1939) in *Lecanidion atratum* and by Cain (1934) in *Sporormia leporina,* was attributed to the fact that observations were made in water mounts. In moist air, on the other hand, ascus dehiscence in these species was "normal," that is, the ectoascus ruptured apically, and the endoascus expanded through the fissure.

One of the most common marine and brackish-water Ascomycetes of the North Carolina coast is *Leptosphaeria discors,* described by Saccardo and Ellis in 1883 (as *Metasphaeria discors*), and recently redescribed and illustrated by Johnson (1956). The fungus usually occurs on rooted *Spartina alterniflora* and *Juncus maritimus,* but viable, mature ascocarps have frequently been found on culm segments of these phanerogams dredged from 30-50 feet of water, 1-2 miles off the coast. Johnson (1956), following Saccardo and Ellis (Saccardo, 1883) described the asci of *L. discors* as ". . . thick-walled, becoming thin-walled at maturity . . ." Obviously, the significance of the thin-walled ascus was not appreciated since no description of *L. discors* mentions the fact that the fungus produces bitunicate asci. Recent observations on two collections of *L. discors,* one from brackish-water (9.7‰ salinity), and one from seawater (35.1‰ salinity), show that normal ascus dehiscence and spore discharge is similar to that described as "abnormal" for such species as *L. acuata* and *L. lemaneae.* This paper is a report on these observations.

Two observational methods were employed. Ascocarps were dissected from stem tissue and mounted in unsterilized seawater in depression slides or Howard Mold Count cells. Some ascocarps were gently crushed in the slide to facilitate observations on ascus maturation. Other ascocarps were mounted whole in the slide, specifically for study of spore discharge. In either case, the fructifications were completely submerged. Crushed and whole ascocarps were also mounted in Van Tieghem cells, and ascus maturation and dehiscence observed as they occurred in a humid atmosphere. A Howard Cell ocular grid facilitated observations on expansion, contraction, and recoil of the asci.

Observations in Water Mounts

Ascus initials are thin-walled and densely protoplasmic. They elongate to a length equal to about half that of an ascus with spore initials, and gradually become thick-walled (Figure 1 J). The ascus usually has a thicker wall at the apex than at the base. Invariably, a very narrow channel appears in the apex of the ascus. This channel gradually becomes longer until it extends through the thickened apical wall (Figure 1 K). A corresponding narrow channel also extends through the thick-walled basal portion (Figure 1 K). Ascospore initials appear, and as they develop into the form of the mature spore (i.e., broadly-fusiform or broadly-ellipsoid) the entire ascus expands in length, but not appreciably in diameter. Concomitant with the increase in length is a decrease in thickness of the intact ascus wall except at the apex and base (Figure 1 G). This suggests that despite the thick wall the ascus is somewhat flexible or extensile. Elongation of the intact ascus is limited, however. A thick-walled ascus measuring 180 μ in length, for example, extended to 203 μ as the inner (or outer) wall became thin. Generally, this increase in length was between 20 and 60 μ.

Ascospore maturation occurs either before the ectoascus ruptures, or after longitudinal expansion of the endoascus. In either case, the spores or spore initials are closely crowded near the basal portion of the ascus as elongation of the intact ascus proceeds to completion. Stages in spore maturation are illustrated elsewhere (Johnson, 1956, fig. 16).

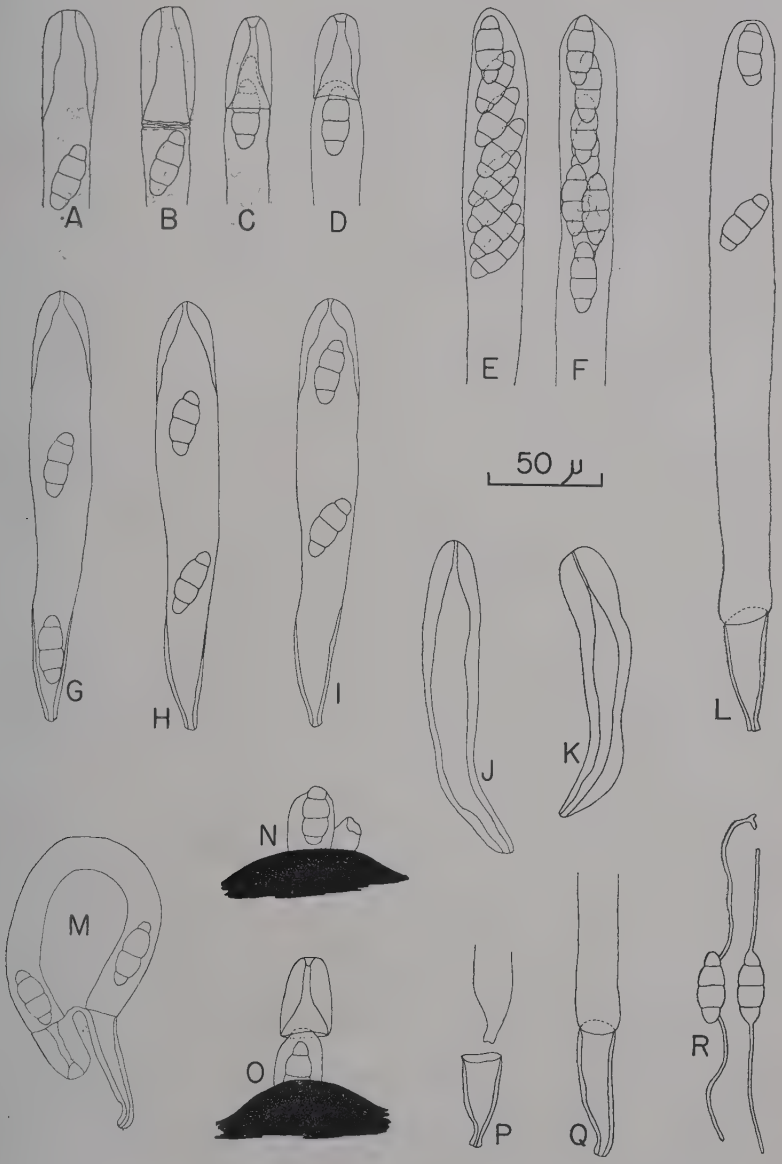
Prior to rupture of the ectoascus, the spores move as a mass toward the ascus apex (Figure 1 G-I). This movement invariably prefaces ectoascus dehiscence. Two factors indicate a high turgor pressure within the intact bitunicate ascus. First, the portion of the ectoascus immediately over the channel apex is taut over the channel (Figure 1 A) prior to ectoascus rupture. Immediately after circumscissile rupture is complete, the apical portion of the ectoascus withdraws slightly into the channel apex (Figure 1 C). Secondly, if the basal portion of the ascus is punctured with a microneedle, there is a sudden rapid movement of the spores from their apical position in the intact ascus toward the base.

The first indication of ectoascus rupture is a conspicuous wrinkling of that portion of the outer wall immediately below the thickened apical portion (Figure 1 B). In one ascus, wrinkling at the apex was concomitant with wrinkling of the ectoascus immediately above

the thickened basal portion. Whether this basal wrinkling occurs consistently is not known. Quite commonly, a thin wall appears in the basal portion of the channel in the ascus apex (Figure 1 C, D) at about the time that ectoascus wrinkling occurs. The impression is that in the two-walled, intact, turgid stage the apex of the endoascus is pressed firmly against the inner face of the apical channel. The appearance of a thin wall within the confines of the apical channel suggests that the endoascus is initially thin, and conversely that the ectoascus is thick-walled.

Circumscissile rupture or dehiscence of the ectoascus occurs just at the base of the thick-walled apex. The endoascus immediately elongates through the opened ectoascus, and in a few seconds reaches a length 1-3 times that of the intact ascus (Figure 1 L). The thickened, thimble-shaped cap is either cast off by the elongating endoascus, later to fall away or is pushed aside as the spores are discharged. In most cases the endoascus expands laterally immediately outside the confining orifice of the ectoascus (Figure 1 Q). This expansion may account for the rapid basipetalous shrinking of the ectoascus. The base of the endoascus is only tenuously held by the basal portion of the ectoascus. Observations on thick freehand sections of perithecia show that quite often the sudden longitudinal expansion of the endoascus is sufficient to tear the endoascus out of the base of the ectoascus (Figure 1 P). Occasionally, circumscissile rupture of the ectoascus is incomplete, in which case the apex and the base of the outer wall remain partially intact (Figure 1 M); contortion of the endoascus invariably results. In a very few instances of incomplete dehiscence, subsequent spore discharge occurred through the base of the endoascus. The length of the ectoascus immediately after rupture is considerably greater than its length after the endoascus has attained maximum longitudinal expansion. Since wrinkling of the ectoascus does not occur except at the apex and

FIGURE 1. *Leptosphaeria discors*. A-D, stages in rupture of ectoascus cap; E, F, pivoting of spores in endoascus prior to discharge; G-I, movement of spore mass toward apex prior to rupture of ectoascus (only the upper and lower spores are shown); J, K, thick-walled, immature asci; L, ascus showing apical position of spores (only upper and lower ones shown) prior to endoascus rupture; M, incomplete circumscissile rupture of ectoascus; N, O, asci protruding through ostiole orifice; P, thick-walled basal portion of ectoascus, and thin-walled basal portion of the separable endoascus; Q, lateral swelling of endoascus immediately above the confining basal portion of the ectoascus; R, spore germination.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perhaps occasionally at the base, deliquescence or shrinking of that portion of the ectoascus remaining after the apical cap is cut off, would appear to account for the length difference.

If intact perithecia are examined in profile, emergence of the asci through the ostiole can readily be observed. As the endoascus elongates after release from the ectoascus, it protrudes for a short distance through the ostiole (Figure 1 O). The thimble-shaped cap may be carried through the ostiole and subsequently sloughed off, or may be torn off as the ascus emerges. Generally, a single ascus emerges, discharges the spore complement, collapses, withdraws into the perithecial cavity, and is replaced by another ascus. Occasionally, 2 or 3 asci protrude through the ostiole (Figure 1 N), but in such instances the asci do not discharge the full complement of spores.

Spore discharge in *Leptosphaeria discors* does not follow the repeater pattern observed in most terrestrial Ascomycetes with bitunicate asci. Prior to spore discharge the apex of the endoascus becomes extremely thin. Presumably, this marks the position of rupture of the endoascus. The uppermost spore presses firmly against the endoascus apex, and apparently the entire column of spores maintains a constant pressure on the apex until rupture occurs. Contrary to the condition in *Plowrightia ribesia,* for example, the spores form a very compact, linear mass in the upper half of the extruded endoascus; as a consequence, the basal portion is devoid of spores (Figure 1 L). The time lapse between maximum elongation of the endoascus and spore discharge is variable, some asci discharging immediately upon attaining a maximum length, others discharging after a delay of from a few minutes to several hours. Spore discharge is simultaneous. The entire column of ascospores flows out through the ruptured endoascus. Consequently, there is no recoil of the ascus as the successive spores leave the apical orifice. Initially, the flow of spores is very rapid, but the last two or three spores move very slowly out through the orifice. Prior to discharge, the spores (with the exception of the apical one) are usually arranged at an angle to the long axis of the endoascus (Figure 1 E), but as discharge occurs the spores pivot and align parallel to the long axis (Figure 1 F). Only infrequently do the spores fail to rotate; in such instances, the spores become wedged in the endoascus orifice, and discharge is incomplete or momentarily retarded. With the release of turgor following spore discharge, the endoascus recoils slightly, but remains thin-walled, even as it retracts into the perithecium.

Observations in Air Mounts

Maturation and rupture of the asci in air mounts (moist air in Van Tiegham cells) follows the same pattern as that described for asci in water. Elongation of the endoascus does occur in moist air, but the magnitude is considerably less than in water. Spore discharge is simultaneous, but is very slow and always incomplete since the endoascus collapses shortly after emergence from the ectoascus.

Although precise measurements of spore discharge distance were not made, the spores invariably fall from the endoascus orifice within a very short distance. The force of propulsion is apparently very low, and may be correlated with low turgor pressure in asci exposed to the air. Glass slides placed 0.1 cm horizontal distance from the ostiole of actively discharging perithecia never collected ascospores, indicating that the horizontal distance of discharge in air mounts is very short.

It appears, therefore, from laboratory observations that spore discharge in *Leptosphaeria discors* probably occurs generally and most efficiently in water. This hypothesis was tested by placing glass slides in clumps of *Spartina* in which *L. discors* was known to occur, and in which the stems were exposed to air during low tide. Exposed slides were examined immediately after the tide had ebbed from the clumps, and others just prior to flood tide. Thus, some slides were exposed to spore discharge in the air, others to spore discharge in water. Spores of *L. discors* were never found on those slides exposed during low tide, even though the slides were less than 1 mm from the *Spartina* stems on which the perithecia occurred. Abundant spores were obtained during the times that the ascocarps were covered by high tide water. This seems conclusive evidence that spore discharge in *L. discors* occurs normally during submersion, and therefore validates observations of discharge in water mounts in the laboratory.

Discussion

Ascus development and dehiscence in *Leptosphaeria discors* follows the general pattern of that of bitunicate asci, that is, entension of an endoascus through an ectoascus. Certain variations, however, stand out prominently. The thimble-shaped cap, consistently in evidence in *L. discors,* has been reported for several Ascomycetes, but is considered an abnormality in the majority of instances where it has been observed. Certainly Butler's account (1939) in the Discomycete *Lecanidion atratum* lends weight to this hypothesis. Of those species

in which a cap is thrown off as the endoascus elongates, most are terrestrial forms. Even in the aquatic Pyrenomycete *Pleospora scirpicola,* Pringsheim (1858) does not mention the presence of a "cap." Ingold (1951) presents evidence that there may be exceptions. Sloughing of a thick-walled cap is apparently characteristic of asci of the fresh-water Ascomycete *Ophiobolus typhae,* and perhaps also of *Ceriospora caudae-suis.* Whether or not spore discharge in these species is simultaneous is not known, although Ingold's figures for *O. typhae* suggest that simultaneous discharge occurs. In the terrestrial *Leptosphaeria, L. acuata,* the evidence presented by Hodgetts (1917) is seemingly conclusive that the thimble-like cap is an abnormality. Judging from the figure by Ingold (1933, Fig. 1 D), *Podospora curvula,* which produces unitunicate asci, may also dehisce in such a manner as to leave an ascus "cap" quite suggestive of that in *L. discors.*

Turning to spore discharge, it appears that this process in *Leptosphaeria discors* is the direct antithesis of that in all species which have been described as having bitunicate asci, with the exception of some species of *Sporormia* (Griffiths, 1901; Ingold, 1933), and perhaps a few species of *Delitschia* (Griffiths, 1901). Spore discharge in *L. discors* is simultaneous, whether in water or moist air. Judging from other accounts of spore discharge (Ingold, 1933, p. 180, for instance) successive or "repeater" type of discharge is concomitant with an endoascus orifice of a smaller diameter than that of the spores. This does not necessarily hold true, since the apical orifice diameter in the endoascus of *L. discors* is clearly smaller than spore diameter, yet the spores are discharged in mass (simultaneous). *Leptosphaeria discors* differs in this respect from the aquatic *Pleospora scirpicola,* in which spore discharge is successive, even in submerged asci.

For those Ascomycetes with bitunicate asci which have been examined in detail, it appears that usually the endoascus is thick, the ectoascus thin. In some species of *Myrangium* (Tai, 1931; Miller, 1938) the reverse is true. While the evidence is not conclusive, it would appear that *Leptosphaeria discors* commonly has a thick ectoascus and a thin, extensible endoascus. Certainly the fact that a thick-walled cap is cut off in a circumscissile manner to expose a thin-walled inner ascus apex lends support to the possibility. Further evidence is found in the basal portion of the ectoascus which remains after the endoascus has emerged (Figure 1 P). Repeated observations

on mature asci of *L. discors* suggest that normally the ectoascus is thick-walled throughout in the immature stages, but becomes thin-walled only in the intermediate region between base and apex. It is well-established, however, that the spores of *L. discors* are not discharged through the channel in the thickened apex of the ascus, and is contrary, therefore, to the method in *Lecanidion atratum,* for example.

The observations on *Leptosphaeria discors* do not, it is felt, justify speculation as to the taxonomic significance of ascus structure and dehiscence, although these criteria have been used extensively in ordinal delimitation (Nannfeldt, 1932; Miller, 1949). Simultaneous spore discharge in *L. discors* and successive discharge in other leptosphaerias certainly raises questions of relationship among these species, and among other Pyrenomycetes with bitunicate asci.

Whether or not the fungi occurring on marine phanerogams are true "marine" fungi may be open to dispute. The criteria which can be applied in designating some lignicolous, salt-water inhabiting fungi as "marine" are, admittedly, not entirely known. In *Leptosphaeria discors,* however, there is a suggestion of one criterion which might be used: spore discharge normally occurring when the ascocarps are submerged in seawater.

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PROTECTIVE COLORATION AND HABITAT OF THE SHRIMP *TOZEUMA CAROLINENSIS* KINGSLEY, (CARIDEA: HIPPOLYTIDAE)[1]

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ABSTRACT

The caridean shrimp *Tozeuma carolinensis* Kingsley is reported as inhabiting colonies of alcyonarians of the genera *Antillogorgia* and *Pterogorgia,* clinging to the branches by means of the pereiopods and uropods. When on grassy bottom the animal is a light greenish color, but when inhabiting the alcyonarians the body and proximal parts of the appendages are dark bluish purple. A gravid female and a male are illustrated, the latter clinging to an alcyonarian. The use of the uropods for clinging is apparently unusual in the Caridea.

INTRODUCTION

The hippolytid shrimp *Tozeuma carolinensis* Kingsley, 1878 is a common caridean living in shallow water along the Atlantic coast of the United States from Vineyard Sound to southern Florida. Schmitt (1935) gives its range as "Vineyard Sound, North Carolina, and Bahamas to Curacao and Yucatan, Porto Rico; St. Thomas; to a depth of 4½ fathoms." It is often taken in seine and trawl hauls in grassy areas. In Florida it has been reported from Soldier Key, Biscayne Bay (Voss and Voss, 1955) and from northwestern Florida by Wass (1955). It commonly occurs in beds of the turtle grass, *Thalassia testudinum,* and Wass (l.c.) states that it is "usually green in color, occasionally brown, with the young translucent."

Despite its common occurrence, *Tozeuma* has apparently never been examined *in situ,* and no comments on its mode of life have been found in a search of the available literature. During the spring and summer of 1955 and 1956 and the winter of 1957, the author observed this species living among the branches of two species of alcyonarians at Soldier Key, Biscayne Bay, Florida. Its coloration and mode of attachment are unusual among the carideans and seem worthy of detailed description.

COLORATION AND HABITAT

In the spring of 1955 when the author was conducting a field trip in Marine Biology to Soldier Key, considerable attention was devoted

[1]Contribution No. 172 from The Marine Laboratory, University of Miami.

to the alcyonarians of the area and specimens were collected for laboratory study and identification. While examining in shallow water an attached specimen of the sea feather, *Antillogorgia acerosa,* it was noted with surprise that several small branchlets about an inch or two in length were broken off and were drifting in the water. What was even more surprising was that when the hand was withdrawn from the colony, these "branchlets" drifted in among the branches of the alcyonarian and disappeared. A second similar performance convinced the author that the "branchlets" were actually small animals living in the alcyonarian, and an attempt was made to collect them for examination.

The animals were difficult to capture, and at first it was thought that, since the creatures assumed a vertical position in the water, they were small pipefish. Eventually a specimen was caught and placed in a collecting jar when it was seen to be a small dark purple shrimp with a very slender body and elongate rostrum.

On that particular field trip there was little opportunity to observe the shrimp in its habitat on the alcyonarian, although it was seen to cling to the branchlets in close alignment to the axis of the alcyonarian, in which position it was almost invisible. It was found that several specimens might be present on a single branch, but they could not be distinguished until they were disturbed. They would then immediately desert their home.

On returning to the laboratory the shrimp were identified as *Tozeuma carolinensis* Kingsley, a common species in the area but which always heretofore was known to be yellowish green or brownish green. When dropped into alcohol, the appendages turned a bright scarlet, the body slowly lost its deep purple coloration and within a few hours the entire animal was colorless.

On March 17, 1956 the author returned to Soldier Key on a collecting trip with the noted Danish marine biologist, Dr. Gunnar Thorson, and this time special attention was turned to the habits of *Tozeuma.* It was discovered that the shrimp could be easily found by drawing the alcyonarians through the hand, forcing the shrimp to desert its hiding place. A large number of the colonies were examined, and about 30 per cent of them yielded from 1 to 5 *T. carolinensis* each.

With the aid of a sea mask observations were made on the manner in which the shrimp clung to the alcyonarians. All of the specimens were found to arrange themselves head downward on either the branches or branchlets. Anteriorly, the pereiopods or walking legs appeared to grip the alcyonarian, but posteriorly the uropods were

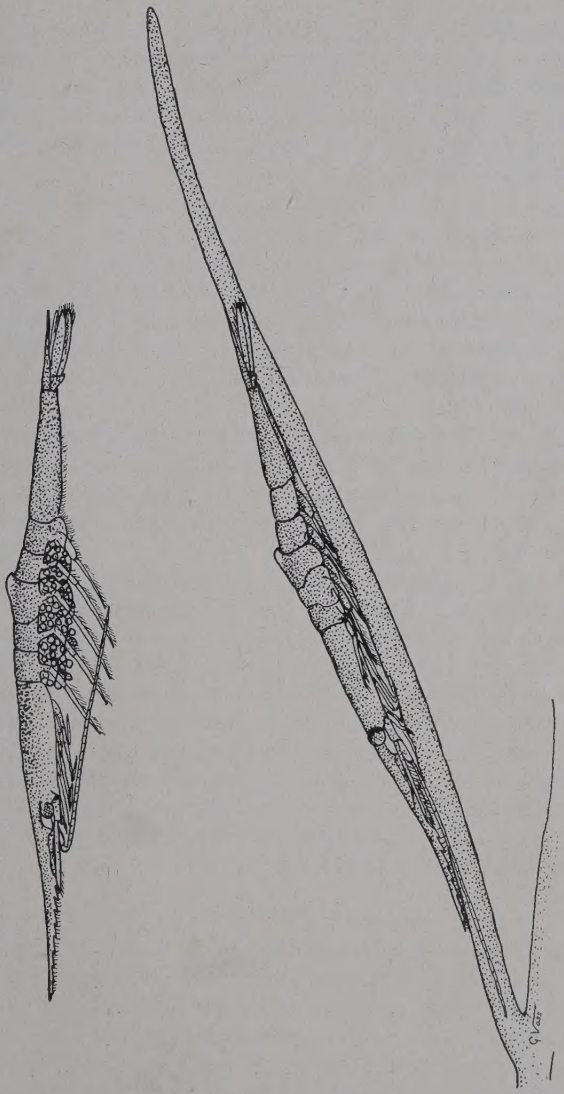

FIGURE 1. *Tozeuma carolinensis* Kingsley. Left is a female carrying eggs, shown in swimming position. Right is a male resting on an alcyonarian. (Redrawn from field notes with aid of preserved material.)

used for attachment, closing sideways upon the branchlet in an efficient manner (Figure 1). Even though there was some surge, causing the alcyonarians to wave about gently, the shrimp were undisturbed. No feeding or other action could be seen. The color of the shrimp was an evenly distributed dark purple, exactly matching the color of the purple alcyonarian.

On April 7, 1956 the author again returned to Soldier Key. On this occasion *Tozeuma* was found living not only on *Antillogorgia* spp., but also a single specimen was collected from near the base of a purple sea whip, *Pterogorgia anceps*. The latter specimen had apparently only recently settled upon the sea whip for about half of its body was a yellowish green. It is probable that it had lately been living among the turtle grass, *Thalassia testudinum*, which grows sparsely throughout the area.

On January 12, 1957 another visit to Soldier Key revealed very few individuals present, perhaps less than 10 per cent of the alcyonarians being occupied. It was thought that this scarcity of *Tozeuma* might be due to the cold weather experienced for several days preceding the visit.

During the periods listed above, numerous individuals were collected from the sea feathers, and, with the single exception noted, all had assumed a dark purple coloration from their association with the alcyonarians. On January 22, 1957, Dr. C. Richard Robins, Marine Laboratory ichthyologist, made several seine hauls on the ocean side of Key Biscayne, Miami and the invertebrates were turned over to the author for identification. In the collections were 9 gravid females and 6 males of *T. carolinensis*, ranging in length from 28.0 mm to 41.0 mm, measured from the tip of the rostrum, to the tip of the telson. All of the specimens were a light green and were collected from dense *Thalassia* beds adjacent to the beach.

Discussion

As nearly as can be ascertained from the literature, the use of the uropods for clasping is unusual among the carideans. This mode of attachment and the coloration of those individuals found living among the alcyonarians would seem to suggest a commensal relationship. This view can hardly be maintained, however, since the more usual habitat of the shrimp seems to be the marine grass beds, where it is normally green in color. According to the distribution records, *Tozeuma* is not even limited to the turtle grass, *Thalassia*, since in its

northern range this warm water species of sea grass is missing, being replaced by the temperate water eel grass *Zostera*.

The adaptive coloration, the long and slender profile, and the perpendicular position assumed by the shrimp when swimming, bring to mind certain pipefish, trumpet fish and certain eels, which normally assume the position and coloration of surrounding grasses for protection from predators.

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